A

ILLUSTRATIONS

OF

ARTS AND MANUFACTURES.

BEING

A SELECTION FROM A SERIES OF PAPERS

READ BEFORE THE

SOCIETY FOR THE ENCOURAGEMENT OF ARTS, MANUFACTURES, AND COMMERCE.

BY

ARTHUR AIKIN, F.L.S. F.G.S. ETC.

LATE SECRETARY TO THAT INSTITUTION.

LONDON:

JOHN VAN VOORST, PATERNOSTER ROW.

M.DCCC.XLI.

LONDON:
PRINTED BY SAMUEL BENTLEY,
Bangor House, Shoe Lane.

TO

RICHARD HORSMAN SOLLY, Esq.

F.R.S. F.L.S. F.G.S. F.H.S. ETC.

My dear Sir,

In selecting some one to whom this book may with most propriety be dedicated, I have had two objects in view, namely, personal esteem and benefits rendered to the Society of Arts. In the latter respect, I am confident that every member of the Institution would accord you the pre-eminence, for your effective unwearied and long-continued efforts, personal and pecuniary, in its service. With regard to myself, it gives me great satisfaction that an opportunity has occurred of publicly acknowledging my obligations to you, for your spontaneous exertions in my favour, twenty-four years ago, when I became a candidate for the secretaryship of the Society; and for a friendship, begun then and continued to the present time, and characterized by an uniform course of kindness and regard.

I am, my dear Sir,

Yours very truly,

ARTHUR AIKIN.

7, Bloomsbury Square,
May 1841.

PREFACE.

In the year 1828 it was proposed to the Society of Arts to appropriate a few evenings to the illustration of the Arts and Manufactures of Great Britain. The proposal, after due consideration, was approved by the Society, and a committee was appointed to carry it into effect and to superintend the details. All the papers read during the two first years were furnished by myself, and the specimens in illustration of them were contributed partly by individual members, and partly by the liberality of other societies and public bodies. By degrees, several members of the Society were prevailed on to give illustrations of those arts or manufactures with which they were personally conversant, whereby a very acceptable variety has been secured to our audience, and the plan has been kept up with spirit to the present time. The number of papers furnished by myself exceeds forty, of which some have been published in the yearly volumes of the Society's Transactions. A selection of these and of those yet remaining in manuscript has been made by me, which, after being carefully corrected, and in many instances considerably enlarged and illustrated

by explanatory engravings, are now submitted to the candour and indulgence of the members of the Society and of the public at large.

As in some of the papers there are allusions to temporary circumstances, I subjoin the date when each was read.

1829.

Jan. 27.—Pottery.

Feb. 10.—Do.

March 10.—Gypsum.

1830.

Jan. 12.—Engraving.

26.—Furs.

March 9.—Paper.

1831.

Feb. 8.—Felting.

June 5.—Horn and Tortoiseshell.

1835.

March 10.—Calcareous Cements.

1836.

April 12.—Antiquarian History of Iron.

May 10.—Metallurgical History of Iron.

1837.

Jan. 10.—Do.

Feb. 10.—Do.

1838.

Nov. 13.—Bone and its uses.

A. A.

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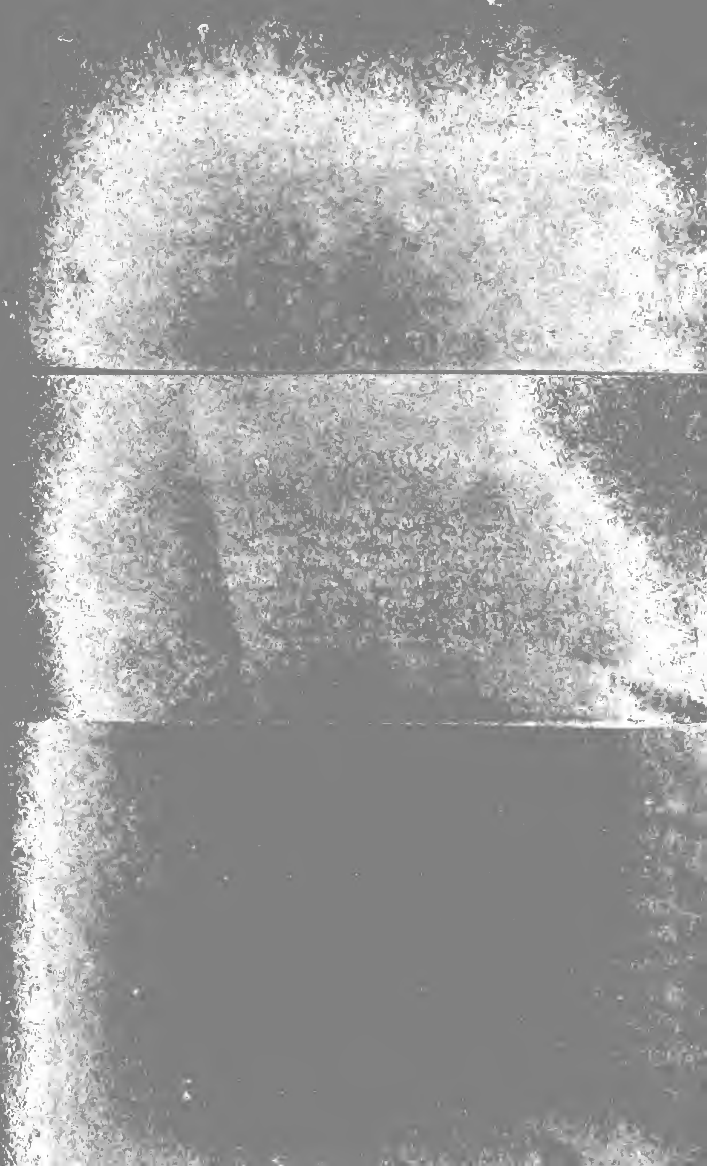

I. ON POTTERY.—Part I.

In the section of the Rules and Orders of the Society of Arts which relates to the duty of the Secretary, he is directed "as much as possible to endeavour to make himself acquainted with the nature and circumstances of the several arts and manufactures of this and other countries." In obedience to these directions, when the plan was first projected to devote a few evenings in the session to illustrate, by the exhibition of specimens, the present state of the Arts and Manufactures of Great Britain, I proposed to collect,

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from such authentic sources as were accessible to me, a sufficient number of particulars to explain the specimens exhibited, and to call forth discussions on them, tending, I would hope, to the rational entertainment of those present, and occasionally to the improvement of those useful and ornamental arts that have so largely contributed to the opulence and civilisation of our country.

It never entered, however, into my thoughts, that if left to my own resources I should be at all able to fulfil the expectations of the Society: but I have had many opportunities, from my official situation, of knowing how well furnished the Society is with men personally and professionally conversant with almost every branch of manufacture. On these I knew that I could rely for all the practical information which our plan requires. I was also well aware that many of our members who rank among the higher classes of society are in possession of rare, and curious, and interesting specimens, illustrative either of the ancient or modern state of art. Some of these treasures, I felt confident, would be offered by the liberality of their owners to the inspection of the Society. I also considered it not improbable that those public and scientific bodies, with whom we keep up an intercourse by the mutual exchange of Transactions and other acts of civility, would occasionally enrich our exhibitions by the loan of specimens. The Society will, I am sure, be much gratified in being informed, that whenever I have made application in their name for information or for specimens, I have not only not

experienced any repulse, but all my requests have been granted with a promptitude, a kindness, and a liberality, beyond my utmost expectations. I shall hereafter have an opportunity of mentioning the names of those from whom has been derived whatever of practical information I may be able this evening to communicate; but I think it right now, on the very threshold of our undertaking, to record the liberality of the Directors of the East India Company, who, at the suggestion of Dr. Wilkins, their librarian, have placed at our disposal such articles in their museum as may fall in with our plan. Those only who know the riches of this collection, in models, in specimens, and in products illustrative of the arts and manufactures of India and other oriental countries, can form an adequate idea of the obligation thus conferred on us by Dr. Wilkins. To Thomas Hope, Esq., one of our members, many thanks are also due, for the valuable and extremely interesting specimens of Etruscan vases and other articles, with which he has enriched this our first exhibition.

The art of pottery, or, to use a still more general term, the manufacture of earthenware, has been selected for illustration on the present and the next succeeding evening; and if adequately treated of with regard to its history, both ancient and modern, to the physical and chemical principles on which it is founded, and to the machinery and manipulations by which its various forms are produced, as well as with reference to the connexion of these forms with the principles of fine art and correct taste, would extend far

beyond the bounds within which it has been thought proper to confine it. If, therefore, some curious and important particulars are only slightly touched, or even wholly omitted, let it be remembered that, compelled as I have been to select, I have, to the best of my judgment, culled out those particulars which appeared to me most likely to interest and inform the curiosity of my audience.

Certain natural earthy mixtures, called clays, possess the property of plasticity; that is, when mixed with water so as to be sensibly moist, they yield readily to pressure in any direction without breaking, and when the pressure is removed, they retain the form given to them, without showing any tendency to return to their original figure. When dried, by the air or by the sunshine or by an artificial heat not exceeding that of boiling water, they acquire a certain degree of hardness; but when pressed by a force greater than their power of resistance, they give way at once, having lost their plasticity, and having become perfectly brittle. These fragments, however, when beaten up with water, compose a mass equally ductile as at first. But if the dried clay has been subjected to a red heat, its hardness is found to be much increased; and its fragments, when broken, are no more capable of forming a mass with water than so much sand. On these two properties of clay, namely, its original plasticity, and its subsequent hardness and resistance to the action of water when burnt, the manufacture of earthenware essentially depends: the former allowing the artist easily to give to the mate-

rial any figure that he pleases, and the latter giving to the ware the requisite firmness, and the capability of holding liquids, and resisting the action of most of them even when boiling hot.

Clay consists essentially of two ingredients, alumina and silica. The first of these it is which, by its combination with water, acquires that pulpy kind of consistence which fits it to be the cement of the mass; the silica is in the state of sand, more or less fine, and may be considered as the passive ingredient. If pure alumina be beaten up with water and afterwards dried, however slowly, it will be found to contract greatly in all its dimensions, and in so doing will become rifty, that is, full of cracks, and will exfoliate and fall to pieces. The addition of sand, especially in the proportion of from five to ten parts of it to one of alumina, leaves the mass still plastic, and diminishes greatly the defects which would attend the use of alumina alone. A red heat, in proportion to its intensity, produces effects on alumina similar to those which evaporation does; the mass contracts, and if it is large or thick, the heat will necessarily be unequally applied; hence arises not only a diminution of bulk, but cracks and warping from the truth of the original figure. But sand, or any other form of silica, which obviates in a great degree the former defects, also corrects these, because it is neither liable to combine with water, nor to undergo permanent contraction by heat. If, now, the natural clays consisted merely of silica and alumina, all their varieties would depend on the relative proportion of the two ingredi-

ents, and on the coarseness or fineness of the grains of sand. The higher the heat to which alumina is exposed, the harder and more compact it becomes, so that at length it will scratch glass, and will not admit water to rise in its pores; and as the mixture of alumina and silica in any proportion is infusible in the heat of our furnaces, it is evident that a great degree of hardness may be given, by high and long-continued firing, to wares made of these ingredients, and that such ware will resist in a great degree the percolation of liquids; but, at the same time, in proportion to its density will be the hazard of warping during the process of being baked.

It is, however, extremely rare to find a clay which contains only the two substances above mentioned. In general, they are mixed with lime in the state of carbonate and sulphate, with magnesia in the state of carbonate, with iron in the state of oxide or combined with sulphur, and with common salt. Almost all these compounds, or at least the bases of them, when exposed to a red heat, act chemically on one another, and on the silica and alumina. The precise nature of these actions has not been ascertained, the matter not having yet been investigated with the care that its importance deserves; but the following particulars may perhaps be considered as sufficiently authenticated.

At a moderate red heat, the iron, if neither lime nor magnesia is present, gives to the mass a colour more or less red. If lime is present in sufficient quantity, the colour given by the iron is cream-brown,

passing into buff. If magnesia is also present (for I am not acquainted with any clay that contains magnesia without lime), the colour of the ware is brownish yellow, or the colour of unburnt ochre.

The carbonate of lime loses its carbonic acid, which escapes in the form of gas through the pores of the ware, provided the carbonate is thoroughly mixed with the other ingredients; but whenever a lump of it, even no bigger than a pea, occurs, a hole reaching to the surface is generally produced, probably by the rapid escape of the gas. Another effect produced by the lime is, that it combines with the alumina; and if the former is equal in quantity to the latter, it greatly diminishes, and, according to Bergman, almost entirely prevents the contraction of the alumina. At a more intense heat, the lime the sand and the alumina melt together into an imperfect glass or slag, which, as it is formed, dissolves the oxide of iron and thus acquires a bluish-black or greenish-blue colour. The common salt is also decomposed; and the soda, which is its base, assists the action of the lime. The magnesia, sometimes at least, combines with sulphuric acid, which it gets partly from the iron pyrites mixed with the clay, and partly from the fuel when coal is made use of. This sulphate of magnesia it is which is occasionally found to cover the outer surface of new-built walls with a saline efflorescence, like hoar frost.

Having now stated the general principles on which the manufacture of earthenware depends, I proceed to give some account of the principal varieties of it

These I shall arrange in groups, characterised for the most part by the greater or lesser elaborateness of the process employed in the preparation of the ingredients, and the beauty, the fineness, and commercial value of the ware itself.

The coarsest and most simple kind of earthenware is that employed in the walls and as the covering of houses and other buildings: of this there are two kinds, bricks and tiles.

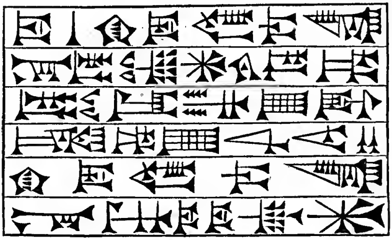
The manufacture of bricks goes up to the very earliest time of historical record. In the book of Genesis, Nimrod is stated to have been the first sovereign, and to have reigned in the land of Shinar, one of the towns of which was Babel. The first building after the flood, of which any mention is made, was the Tower of Babel. It is expressly stated that well-burnt brick was used instead ot stone in these constructions; and that slime, which is generally understood to be bitumen, was employed instead of mortar. Considerable progress appears to have been made in building both the city and the tower before what is called the confusion of tongues took place, in consequence of which the work was abandoned. Nearly on the same site was afterwards founded the celebrated city of Babel, or Babylon; which is described by Herodotus, the oldest Greek historian, as surrounded by a deep and wide trench, the earth from which was formed into bricks. These bricks were then burnt in furnaces or kilns, and were employed part in lining the trench, and the remainder in building the walls: the cement used was

hot bitumen, and between every thirty courses of bricks was a layer of mats composed of reeds. The ruins of Babylon are still visible, in the form of hillocks or high mounds, and have been visited of late years and described by several travellers. The late Mr. Rich appears to have examined these remains with great care, and from his memoir the following particulars, as far as relates to our immediate subject, are derived. Most of the mounds appear to have a certain degree of connexion with one another; but the largest of the mounds, the Birs Nemrood, together with another adjacent, called Akerkouf, is so far distant from the others as to render it doubtful if it could have been included within the extent of the Babylon described by Herodotus.

The connected mounds present walls and passages, or galleries, formed of well-burnt brick, laid in lime-mortar of extreme toughness; but in one of them, called the tower of Belus, large solid masses, or fillings up between the wall, are observed of unburnt bricks. These latter are more rudely shaped than the burnt bricks, being rather clods of earth, composed of a kind of clay-mortar, intermixed with chopped straw to prevent it from falling to pieces: these unburnt bricks are laid in very thick cement of clay, with layers of reeds above the courses of brick.

The Birs Nemrood is at present a mound 762 yards in circumference, and 198 feet high; it consists of three steps, or receding stories: the interior of the mass appears to consist of layers of unburnt bricks set in clay, sometimes without layers of reeds, sometimes

with them, laid between every five or six courses of bricks. This mass is in some parts faced (and probably when perfect was completely so) with layers of burnt bricks set in bitumen. These bricks are about thirteen inches square by three inches thick, and have indented inscriptions, apparently made by a stamp, in a character at present wholly unknown, the elements of which appear to have been representations of arrows or broad-headed nails variously combined together. The bricks are laid with the written face



downward, so that they were not visible on the front of the wall. At the top of the mound is a solid pile, thirty-seven feet high, of burnt bricks, with inscriptions, and set in lime-mortar.

From the proportions of the three stories that now remain, it seems probable that the mound or pyramid consisted, or perhaps was intended to consist, of five stories; the three lower of which were solid, and the two upper would probably have contained chambers. Whether this pile is the unfinished tower of Babel or

not, is at present only matter of conjecture: its local situation with regard to the other mounds is rather in favour of the hypothesis; and the specimens of bricks now exhibited, which were obtained from this very mound, will be regarded with no small interest; they form part of the collection of the East India Company. (See the right hand figure in the Vignette at the head of this paper.)

The manufacture of bricks was also known to the ancient Egyptians. Everybody is aware that one of the modes of oppression practised by this people towards the Israelites, was the unreasonable requisition from them of a certain number of bricks: it is not mentioned that these bricks were burnt; indeed, the circumstance of their being mixed with chopped straw, like the unbaked bricks found in Babylon, renders it probable that they were only sun-dried. Herodotus also records of Asychis, one of the kings of Egypt, that he built a pyramid of bricks made of the mud or silt dredged up from the bottom of the river. This is perhaps the same as that called by Pococke the pyramid of Mensheh-dushour, and by Norden the pyramid of Meidun: it was visited by both these travellers and is described by them as consisting of five degrees, each 50 feet high, and the base 157 by 210 feet; it is formed of unburnt bricks, composed of a mixture of clay and chopped straw. Such unburnt bricks, Pococke adds, are still used in Egypt. It is probable that in the time of Pliny the elder, who lived in the reign of Vespasian, unburnt bricks were in use elsewhere on the north coast of Africa;

for that author mentions, that at Utica no bricks were allowed to be used that had not been dried five years in the sun; a regulation which apparently would be absurd if applied to baked ones. But sun-dried bricks may rather be considered as a kind of artificial stone than earthenware; and, from the circumstance of chopped straw being mixed with them, the clay was probably much more sandy and less tenacious than that required for burnt bricks, and approached nearly to the loam employed at present in building walls by ramming, or *en pisé;* a mode of construction which also was well known to the ancients; Hannibal having constructed several towers on the coast of Spain of this material.*

Certain other celebrated buildings of high antiquity were also formed of brick: such were the palaces of Crœsus at Sardis, of Mausolus at Halicarnassus, and of Attalus at Tralles; all of which were still remaining in the reign of Trajan. That part of the walls of Athens which looks towards Mount Hymettus, as well as some of the more ancient temples in that city, were also built of brick.

In ancient Rome, if the recorded saying of Augustus, that he found the city of brick and left it of marble, be of any authority, the public buildings must have

* Quid? non in Africâ Hispaniâque ex terrâ parietes, quos appellant formaceos, (quoniam in formâ circumdatis utrimque duabus tabulis, inferciuntur veriùs quàm instruuntur) ævis durant, incorrupti imbribus, ventis, ignibus, omnique cæmento firmiores? Spectat etiam nunc speculas Hannibalis Hispania, terrenasque turres jugis montium impositas.—*Plin. Hist. Nat.* xxxv. 48.

been generally of baked brick;* but this material does not seem to have been much employed in the construction of private houses, many of which were wattled, or of wicker-work, covered with clay, raised on low walls of unbaked bricks. Whenever works were erected by the Romans of flints or of other rough unsquared stones, they were in the habit of interposing occasional courses of flat thin bricks, to strengthen the building and to keep it upright. Many such examples are to be found in our own country, where permanent Roman stations occur. The walls of Richborough near Sandwich, the tower supposed to have been a light-house on the summit of Dover castle, the station of Garrienum (now Borough camp), at the conflux of the Yare and Waveney in Norfolk, and the walls at Lympne near Hythe, are among the most perfect and remarkable. All the Roman bricks that I have seen are of a deep red colour, very compact, and well burnt. They probably were composed of natural clay, not containing lime, and merely sifted, either dry or by washing over, in order to separate the stones and coarser sand.

In Bengal, and generally in the wide alluvial valley of the Ganges, bricks are the usual material for build-

* According to the statement of Mr. Jos. Woods, (Letters of an Architect, &c. 2 vols. 4to.) of all the monuments remaining at Rome none prior to the reign of Augustus is of burnt brick. All the great ruins, the Baths, the Colosseum, the Temple of Peace are in great measure of brick. He also mentions that the columns in the court of the Temple of Isis, at Pompeii, are of the same material.

ings of any solidity; and they appear to have been used in this country from very high antiquity, and to have been employed even in the ornamental parts of architecture.

Dr. Wilkins informs me that bricks are made in India by tempering clay, then spreading it on a mat and making it of an uniform thickness, and when it is half dry dividing it into bricks: these bricks are then baked in clamps. But it has sometimes happened, in consequence of those hostile incursions by which India has been so often desolated, that when a district has been laid waste and not reoccupied for several years, clamps of bricks ready for burning have been abandoned. On the return of the inhabitants such clamps have been found so much injured by the rains, and other causes, as not to be worth the expense of burning: some of these mounds still remain near Benares, and have been cited by careless travellers as ruins of buildings of unburnt brick, a material for construction which appears never to have been employed in India.

In Nipal, a hilly country north of Bengal, bricks are made of remarkable compactness of texture: they are of a brownish-red colour, and are very micaceous; so that the clay of which they are formed has probably originated from the decomposition of granite. Some of these, from the East India Company's museum, are now before the Society. Not only the texture of these bricks, but the elegance of their ornamented surface, deserve notice; the sharpness and depth of cutting are such as to make it probable that

they were moulded plain, and that the ornaments were afterwards cut, before the process of burning. (See Vignette, page 1.)

In China, bricks are made of blue clay more or less sandy: the specimens before the Society have evidently not been burnt; they nevertheless do not disturb the clearness of water after lying in it for many hours. When burnt they become of rather a pale red, with a compact, almost semi-porcelanous texture.

I am not sufficiently acquainted with the history of the art of brick-making to state to you the date and particulars of its introduction into the different countries of modern continental Europe. It was certainly practised largely in Italy in the beginning of the fourteenth century; and Mr. Hope informs me, that the brick buildings erected at this period in Tuscany, and other parts of the north of Italy, exhibit at the present day the finest specimens extant of brick-work. In Holland and the Netherlands, from the scarcity of stone, brick was used at an early period and to a great extent, to supply the wants of a dense and rich population.

In England, from the time of the Romans to the eleventh century, there is no evidence of the use of bricks as a material for building. But about that time the abbey of St. Albans was erected, and bricks were employed in its construction; the probability however is, that these materials were obtained from the ruins of the adjacent Roman town of Verulam. St. Botolph's Priory, at Colchester, was founded thirty

years after the abbey of St. Albans, and of this building brick is the principal material. The form of these bricks might justify a suspicion that these likewise were taken from some Roman building; but it is just as likely that the Roman bricks would furnish the model for the earliest made English bricks, and an additional reason for this may be derived from the name *wall tile* having long preceded that of brick. King's Hall, Cambridge, was built of bricks in the reign of Edward the Third, at which time it appears that the price of them was from 6*s.* to 6*s.* 1*d.* a thousand.* The use of this material seems, however, to have been for some centuries almost wholly confined to public buildings and large mansions, for Holinshed, in the introduction of his "History of Queen Elizabeth," enumerating the materials employed at that time for building houses, omits all mention of brick.

Till lately, bricks appear to have been made in this country in a very rude manner. The clay was dug in the autumn, and exposed to the winter frosts to mellow; it was then mixed, or not, with coal ashes, and tempered by being trodden by horses or men, and was afterwards moulded, without it being considered necessary to take out the stones. The bricks were burnt in kilns or in clamps: the former was the original mode, the latter having been resorted to from motives of economy. When clamps began to be employed I do not know; but they are mentioned in an act of parliament passed in 1726, and therefore were

* I *Essex* in Archæologia, iv. 73.

in use prior to that date. The following, in few words, is the present process of brick-making in the vicinity of London, for the practical particulars of which I am indebted to Mr. Deville and Mr. Gibbs.

It is chiefly, I believe entirely, from the alluvial deposits above the London clay, that bricks are made in the vicinity of the metropolis; and a section of these deposits generally presents the following series, such as would naturally result from a mixture of stones, and sand, and clay, and chalk, brought together by the force of water, and then allowed to subside. The lower part of the bed is gravel, mixed more or less with coarse sandy clay and pieces of chalk; this by degrees passes into what is technically called malm, which is a mixture of sand, comminuted chalk, and clay; and this graduates into the upper earth or strong clay, in which the clay is the prevailing or characterising ingredient, the proportion of chalk being so small that the earth makes no sensible effervescence with acids. Bricks made of the upper earth, without any addition, are apt to crack in drying, and in burning they are very liable to warp, as well as to contract considerably in all their dimensions: on this account they cannot be used for the exterior of walls; and a greater number of such are required for any given quantity of work than of bricks, which, though made in the same mould, shrink less in the baking. The texture, however, of such bricks is compact, which makes them strong and durable. Bricks formed of this clay, whether mixed or unmixed, are called stocks; it was formerly used

unwashed, and when the bricks were intended to be kiln-burnt, or *flame-burnt,* to use the technical word, no addition was made to the clay. If they were intended to be clamp-burnt, coal-ash was mixed during the tempering. Of these and all other clamp-burnt bricks the builders distinguish two kinds, namely, the well-burnt ones from the interior, and the half-burnt ones, or place bricks, from the outside of the kiln.

The calcareous clay or malm earth requires no addition of sand or chalk, but only of ashes. The bricks made of it differ from those made of the top earth, in being of a pale or liver brown colour, mixed more or less with yellow, which is an indication of magnesia. The hardest of the malm bricks are of a pale brown colour, and are known by the name of grey stocks; those next in hardness are called seconds, and are employed for fronts of the better kind of houses; the yellowest and softest are called cutters, from the facility with which they can be cut or rubbed down, and are used chiefly for turning the arches of windows. What I have said of top earth and malm earth must be understood, however, to refer to well-characterised samples of these varieties, but, as might be expected, there are several brick-fields that yield a material partaking more or less of the qualities of both, and therefore requiring corresponding modifications in its manufacture.

Brick earth is usually begun to be dug in September, and is heaped rough, to the height of from four to six feet, on a surface prepared to receive it, that it may have the benefit of the frost in mellowing it and

breaking it down. It is then washed by grinding it in water and passing it through a grating, the bars of which are close enough to separate even small stones. The mud runs into shallow pits, and is here mixed with chalk ground with water to the consistence of cream, if any calcareous ingredient is required. When it has become tolerably stiff by drying, coal ashes (separated by sifting from the cinders and small pieces of coal) are added, in the proportion of from one to two and a half inches in depth of this latter to three feet of clay, the most tenacious clay requiring the greatest quantity of ashes. The ingredients are then to be well mixed; and, finally, the composition is to be passed through the pug-mill,* in order to complete the mixture and to temper it. The moulder stands at a table, and the tempered clay is brought to him in lumps of about 7 or 8 lbs.: the mould is a box without top or bottom, $9\frac{5}{8}$ inches long, $4\frac{3}{4}$ wide, and $2\frac{3}{4}$ deep;† it lies on a table: a little sand is first sprinkled in, and then the lump of clay is forcibly dashed into the mould, the workman at the

* The pug-mill is an iron cylinder set upright, in the axis of which an arbor or shaft revolves, having several knives, with their edges somewhat depressed, projecting from it and arranged in a spiral manner round the arbor. By the revolution of the arbor the clay is brought within the action of the knives, by which it is cut and kneaded, and finally is forced through a hole in the bottom of the cylinder.

† A malm brick of the above dimensions will shrink by burning to the length of 9 or $9\frac{1}{4}$ inches. A brick made of top clay without any mixture of chalk, will often shrink to $8\frac{1}{2}$ inches.

same time rapidly working it by his fingers, so as to make it completely close up to the corners; next he scrapes off with a wetted stick the superfluous clay, throws sand on the top, and shakes the brick dexterously out of the mould on to a flat piece of board, on which it is carried to a place called the hacks; here it remains till dry enough to handle: the bricks are then formed into open hollow walls, which are covered with straw to keep off the rain; here they dry gradually, and harden till they are fit to be burnt. A raw brick weighs between 6 and 7 lbs.; when ready for the clamp it has lost about 1 lb. of water by evaporation.* A first-rate moulder has been known to deliver from 10,000 to 11,000 bricks in the course of a long summer's day, but the average produce is not much more than half this number.

The price of bricks varies from forty to sixty shillings a thousand, of which not more than one shilling and three pence a thousand, at the utmost, can be the cost of moulding, assuming the average work of a

* From some experiments made in France we learn the following particulars:—A mould 8 inches 3 lines long, 4 inches, 3 lines broad, and 2 inches 2 lines thick, yielded bricks which on an average weighed, when first made, 5 lbs. 14 oz. When dried and ready for the kiln they weighed 4 lbs. 8 oz. having lost 22 oz. of water: 9 oz. of this quantity evaporates in the first twenty-four hours, the other 13 oz. require five or six weeks to evaporate. By burning, 4 oz. more of volatile matter is driven off: a well-burnt brick of the above dimensions weighing 4 lbs. 4 oz. A fresh-burnt brick when laid in water absorbs about 9 oz. *i. e.* from one-seventh to one-eighth of its weight.

It appears, however, from experiments by M. Gallon, that the weight of bricks varies according to the care with which the clay

moulder to be five thousand in a day; any improvement, therefore, calculated to save time in this department of brick-making by the introduction of machinery worked by steam, or by horse power, can only amount to a benefit equal to a fraction of one thirty-second or one forty-eighth of the entire price of the commodity. If we assume such machine to produce fifty-two million bricks in a year, this amounts to two millions a week (for the season for brick-making in this country continues no longer than from April to September inclusive) or three hundred and thirty thousand in a day, equal to the labour of sixty-six men or eleven horses, without making any allowance for friction, or any deduction on account of temporary repairs. The cost of hand-moulding fifty-two million bricks at one shilling and three pence per thousand is 3250*l.* from which, if we deduct the first cost and repair of machinery, the expense of fuel or of horses, of superintendence, &c. it would probably be found that nothing would remain for profit.

Bricks are burnt either in kilns or in clamps. In

is worked or tempered. Some clay was well worked, and then beaten for half an hour, on the morning of the next day it was again worked and beaten as before, and in the afternoon was again beaten for a quarter of an hour, and was then made into bricks. Another parcel of bricks was made of some of the same clay, treated in the usual manner. Both parcels were dried in the air for thirteen days, when it was found that those made by the former process weighed on an average 5 lbs. 11 oz. each, while those made by the latter weighed 5 lbs. 7 oz. Both kinds were burnt together for ten days; they underwent no relative change in bulk, but the weight of the former was 5 lbs. 6 oz. and of the latter 5 lbs. 2 oz.—*Arts et Métiers*, vol. iv.

the former the burning is completed in twenty-four hours ; in the latter it requires from twenty to thirty days, but is on the whole cheaper, notwithstanding that the loss from over-burning, from under-burning and other accidents amounts to one-tenth of the whole number of bricks.

The consumption of London is for the most part supplied from the brick-fields that surround it in all directions, the principal of which, however, are situated north of the Thames, at Stepney, Hackney, Tottenham, Enfield, Islington, Kingsland, Hammersmith, Cowley, Acton, and Brentford. Those made at Grays Thurrock, Purfleet, and Sittingbourne, are of a very good quality and a fine yellow colour ; stone-coloured ones are made near Ipswich, and have been largely employed in the outside walls of some of the new churches of the metropolis. At Cheshunt, in Hertfordshire, is a bed of malm earth of the finest quality, no less than twenty-five feet in depth ; from this are made the best small kiln-burnt bricks, called paviers. They are hard, absorb very little water, and are used for paving the floors of stables, wash-houses, &c. They have entirely superseded the use of Dutch clinkers, which formerly were imported from Holland in large quantities. The red sandy bricks called Windsors are made at Hedgerley. There is a considerable exportation of bricks from London ; many being sent to the West Indies, to Quebec, and to other colonies.*

* The whole number of bricks made in Great Britain and Ireland in the year 1835, on which the excise duty was paid, was 1380 millions.

Tiles, from the purpose to which they are applied, namely, roofing houses in order to shoot off the rain, require a texture as compact as can be given to them, consistent with a due regard to economy. The fattest and most unctuous clays are, therefore, those which answer the best, especially if free from gravel and the coarsest sand. The price of tiles, compared with that of bricks, is such that the manufacturer can afford to dry them under cover; while, being not more than one quarter of the thickness of bricks, the drying is more speedily performed, and with far less hazard of warping or cracking: the same also is the case with the baking. Sand is added to the clay, but sparingly; for if, on the one hand, it prevents the ware from warping, yet, on the other hand, it increases the porosity, which is a fault especially to be avoided. The general manipulations of grinding the clay and tempering it are analogous to those already described for making bricks; but more pains are bestowed in getting it to the utmost degree of plasticity so as to allow of its being rolled, like dough, into cakes of a proper thickness, which are afterwards brought to the required shape by pressing them into a mould.

The material employed at the manufactories of tiles in the neighbourhood of London is either the bed of blue clay, called by geologists the London clay, or the plastic clay which lies below the former. The tileries north of the Thames, at Hackney, Clapton Terrace, Hornsey, and Child's Hill near Hampstead, are on London clay; those near Woolwich are on the plastic clay. The same clay answers well for sugar-cones,

for garden pots, and all articles of common red ware that do not require to be glazed, and in which a certain degree of porousness is no objection to their use.

If well-tempered clay be placed on a horizontal board, to which, by any simple machinery, a movement of rotation on its centre is given, it is evident that a tendency to centrifugal motion will be communicated to the clay, which, though not of itself sufficient to overcome the tenacity of the earth, will extremely facilitate the action of the fingers in forming out of the mere lump either solids or hollow vessels, of every conceivable variety, consistent with the condition that the section of such vessels in any part at right angles to the axis shall be a circle. The board above described is called the potter's wheel or lathe. By whom it was invented is not known; for in the most ancient records it is spoken of as an implement familiar to every one. The potter's wheel is frequently mentioned in the Jewish writings;* and Homer, the most ancient of the Greek authors, has a comparison the subject of which is a potter turning round with his hands a newly fitted wheel to see if it runs true.† In some parts of India and China, where implements and tools for the manufacturer are re-

* "I went down to the potter's house, and behold he wrought a work on the wheel; and the vessel that he was making of clay was marred in his hands; so he made it again into another vessel, as seemed good to the potter to make it."—*Jerem.*

† ——ὡς ὅτε τις τροχὸν ἄρμενον ἐν παλάμῃσιν
Ἑζόμενος κεραμεὺς πειρήσεται αἴ κε θέῃσιν.—*Iliad*, xviii. 600.
As some potter, seated, tries with his hands the well-fitted wheel whether it will run.

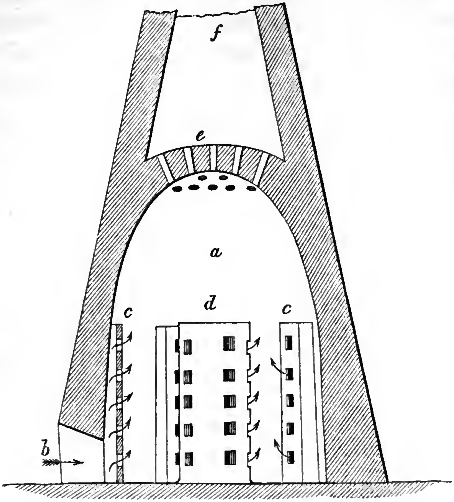
duced to their utmost possible degree of simplicity, the potter squats on the ground, turning the wheel on its spindle with his feet, while he moulds the clay with his hands. In this country, and I believe in general throughout Europe, the workman turns the wheel by a treadle, as he sits or stands to his work; and, when the article to be made is large and heavy, the motion is given by an assistant working at a vertical wheel. In large establishments, where many of these wheels or lathes are in use, a steam engine is generally employed as the prime mover. It is impossible to describe by words the facility and quickness with which the clay obeys the hand of the workman and takes the figure required; it must be seen in order to be truly judged of; and few processes are more entertaining to the bystander, because there are none in which the effect more immediately follows the application of the cause, and in which the material is so completely under the control of the workman, adapting itself to his taste, his whim, his caprice; in which the form that has been just given may be annihilated by a touch, and the material may be immediately made to assume its former, or a wholly different figure. No wonder, therefore, that "clay in the hand of the potter," is so often and so impressively used to denote the relative situations of man and of Him who guides and moulds our purposes at his pleasure.

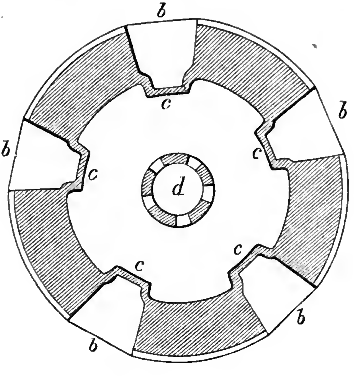
I shall now proceed to give a brief account of the manufacture of the common red pottery ware, as practised in the neighbourhood of London, and in

various other parts of the kingdom; for the principal particulars of which, as well as for the specimens in illustration of it, I am indebted to Mr. Jones, of Lambeth. The material is a yellowish brown clay, from Deptford, there being no other near London on which the glaze will spread with the equality that is required. In general the clay is used without any addition; but such parcels as are too fat or tenacious are brought to a proper state by mixture with loam. The clay is watered and turned, but contains no stones, and therefore does not require to be washed over. It is finally passed through the pug-mill in order to temper it. The required form of a pot or pan, or any other article, is given to it on the wheel, and the ware is dried under cover till it has acquired a considerable solidity. The glaze is then put on in the state of cream, by means of a brush, care being taken to cover the whole surface as evenly as possible: for small articles, such as pipkins, that are glazed only internally, a little of the cream is poured in and then poured out again, a sufficient quantity of the glaze adhering to the bibulous surface of the ware.

The materials of the glaze are galena, commonly called potter's lead ore, ground to an impalpable powder, and then mixed with clay diffused in water, technically called slip. This glaze is transparent, and of a pale yellow colour, and consequently shows through it the colour of the ware; if a black opaque glaze is required, one part of common manganese is added to nine parts of galena. After the glaze is laid on, the ware is again dried, and is then piled in the

kiln in order to be burnt or fired. The annexed figures represent a section and plan of the kiln in





common use. *a*, is the body of the kiln; *b*, the fire-places; *c*, the ascending side flues, with lateral holes to distribute the heat; *d*, a circular flue, occupying the middle of the kiln, with side holes to admit the heat to the interior; *e*, holes in the top of the kiln for the escape of the smoke; *f*, the chimney. For the first twenty-four hours a very low heat is applied, in order to drive all the moisture out of the ware; it is then exposed for twenty-four hours more to a heat nearly as high as it can bear without fusion, which has the effect of baking the clay, of driving off the sulphur from the lead ore, and of causing the oxide of lead to form a frit or imperfect glass with the clay, the other ingredient of the glaze. The fire is now fed with bavin wood instead of coal, by which the heat is increased, the furnace is filled with flame, and the frit being converted into a perfect glass, flows uniformly over the surface of the ware. The fire is then allowed to go out, and when the furnace has become cool, the contents are removed. If the air has been still during the burning, and due care has been observed, the articles in every part of the kiln will be properly baked; but a high wind always renders the heat very unequal, so that the ware in the windward part of the kiln will not be baked enough, while that in the leeward part will be overburnt and run to a slag.

All articles of earthenware which after being baked are opaque, are more or less porous; and if a heat somewhat approaching to their point of fusion, so as to render them slightly translucent, cannot safely be

applied, it is evident that such ware is not very proper for vessels employed in cookery and for several other purposes, from the difficulty of keeping them clean and from their liability to crack when set on the fire in a damp state. In England, we endeavour to obviate this imperfection by means of a thick vitreous glaze; but as the ware itself is very fusible, the glaze must be still more so; and as oxide of lead forms the cheapest and most fusible glaze, this accordingly is the material universally employed by us. But there is a very serious objection to the use of this glaze, namely, that it is soluble in vinegar, in the juice of most fruits, especially when hot, and also in boiling fat; the consequence of which is, that the food of the lower classes, by whom alone cooking vessels of glazed red ware are employed, is often contaminated with lead so as seriously to impair their health, by occasioning colics and the other usual effects of lead poison. Possibly borax, which is now a cheap article and is very fusible, might be made to supersede the use of lead; if not, the only way of avoiding this very serious hazard to health will be the use of more refractory clay, which, consequently, would allow the employment of a less fusible glaze free from excess of lead. This has been done by Mr. Meigh, a potter in Staffordshire, to whom the Society awarded a medal for his invention: the ware produced by him is far superior to that in common use, and well deserves the encouragement of the public. A species of ware, somewhat superior to our common red ware, is made at Lambeth, of Maidstone clay, being of a

paler colour, and a more compact texture than the latter, but does not take an uniform covering by the common glaze for red ware; it is therefore chiefly used for purposes which admit its employment in an unglazed state, or in situations where the imperfection of the glaze is not perceived, as in ornamented chimney-pots, gas-consumers, &c.

The natives of Peru, as Captain Bagnold informs me from his own personal observation, mould their earthenware by hand alone without a lathe, and are in the habit of rendering it impermeable by water, by rubbing it while hot with tallow, which being partly charred, fills up the pores and at the same time gives the ware a black colour, of which the specimens now before you are examples. The Etruscan and Greek vases are covered by a black carbonaceous non-vitreous varnish, which evidently wears off by long handling, and may possibly have been produced by a process similar to the Peruvian. The pottery of Samos, which was in great request among the ancients, especially for cooking-vessels, has a red covering, seemingly semi-vitreous. Wine and oil jars were rendered by the ancients impenetrable to moisture, as they are at present by the people of Spain and Italy, by rubbing them with wax; but for holding dry substances no glaze or varnish was required. Statues of the gods were in Rome very generally made of terra cotta,* that is, of red ware, till the conquests of Sylla, Lucullus, and Pompey, by their

* Fictilibus crevêre Deis hæc aurea templa."—*Propert.* iv. 1, 5.

large introduction of Greek statues of marble, changed the fashion. Other uses of red ware among the Romans were for tiles and water-pipes; and Pliny states, that M. Varro and others directed that their bodies when dead should be deposited in earthenware.*

A more perfect, and indeed very excellent species of earthenware, is that called stone ware, originally introduced from Holland, and now made in several parts of the kingdom and especially at Lambeth. To one of the principal manufacturers of this ware, Mr. Wisker, I am indebted for the specimens on the table, and for the following particulars.

The materials are, pipe-clay from Dorsetshire and Devonshire, calcined and ground flint from Staffordshire, and sand from Woolwich and Charlton.

The clay is pulverised and sifted dry, and is either used alone, when an article of great compactness is required, as soda-water bottles, or is mixed with sand to diminish its contraction in the fire. For retorts and other large vessels, instead of sand, the refuse stone ware, ground to a fine powder, is used. For the finer articles, such as figured jugs, ground flint is employed in place of sand. The composition is brought by the addition of water, to the state of mortar, and is then tempered in the pug-mill. All round articles are made on the horizontal wheel; and those of great size, *i. e.* of a greater capacity than two gallons, are at first of extraordinary thickness

* Hist. Nat. xxxv. 46.

below to support the upper part; when they come off the wheel they are dried, and then are put on a lathe and shaved down to a proper thickness. For oval and other figures not circular, as pans for salting hams in, the clay is formed in a mould to the required shape. The drying, especially of large articles, must be very carefully performed; and as, from custom, the tops or bottoms of jars and various other vessels made of this ware are required to be of a deeper brown than the natural colour of the materials, they are dipped so far in a mixture of red ochre and clay slip. When perfectly dry they are piled in the furnace, bits of well-sanded clay being put between each piece to prevent them from adhering. A slow fire is kept up for twelve to

twenty-four hours, according to the thickness of the ware, capable of bringing it just to a low red heat. The fire is then to be raised till the flame and the ware are of the same colour, and is so to be continued for several hours. At this time the glaze is added, which is done by pouring down the holes in the top of the kiln, twenty or thirty in number, ladlefuls of common salt. This, being volatilised by the intense heat of the interior, attaches itself to the surface of the ware; here it is decomposed, the muriatic acid flying off, and the soda remaining behind in union with the earth with which it forms a very thin, but, on the whole, a perfect glaze; at least quite sufficient, with the compactness of the ware, to render it completely proof against the percolation, not only of

water, but of the strongest acids. So perfect, indeed, is the texture of the best ware now made, that it has of late been very largely used in the construction of distillatory vessels for manufacturing chemists, instead of green glass, as being less frangible, and also cheaper. Pickling jars, and many other vessels in which acid substances for food or condiment are kept, as also those earthen vessels in which great strength is required, are best made of stone ware. Vauxhall is the chief seat of this manufacture near London, where are now about eight houses engaged in this fabric, most of which are very actively employed, as the use of it is considerably on the increase.

ON POTTERY. Part II.

The ancient Greeks appear to have been wholly unacquainted with the art of covering earthenware with a vitreous glaze; at least neither Pliny, nor other authors whom I have consulted on the subject, say anything about it, nor am I aware that any specimens of glazed ancient Greek or Roman pottery exist. For heating water and other liquids in, metallic vessels were generally, perhaps universally, employed; and although cold liquids were kept and conveyed in earthen vessels, the natural porousness

of the ware was corrected by a varnish of wax or resin, or it was covered with a thin, black, non-vitreous varnish, one method of producing which I have already pointed out. It may be seen on all the so-called Etruscan vases; and from these was liable to be worn off by long use, as evidently has happened with the lower part of the vase belonging to Mr. Hope, which was exhibited at our last meeting.

Vitreous glazes, whether employed simply for closing the pores of baked clay, and thus rendering it impermeable to water, or with the farther intention of concealing the coarseness and bad colour of the body by a covering of enamel, probably originated in China, whence they may have passed to India. The conquest of the vallies of the Indus and Ganges about the year 1000 by Sultan Mahmoud, the Gaznevide, was perhaps the event which, as it first introduced the Moslems to India, may have made them acquainted with the use in architecture of glazed tiles of various colours. The taste for this kind of ornament, and the art of making it, appear to have been very generally diffused through all the Mahometan states. The similarity of their architecture in the wide extent of country from the Ganges to Gibraltar, shows not only a coincidence of feeling, but a community of intercourse. It appears, therefore, by no means improbable, that an invention which was so largely and generally applied to decorative purposes in Mahometan architecture, should have travelled in no long time from India to Spain.

The palace of the Moorish kings at Granada, called

Alhambra, was built in 1280, and many of the rooms are represented as ornamented by lacquered tiles. The tomb of Sultan Mahomed Khoda-Bendeh, at Sultanieh, in Persia, was also built in the thirteenth century; and of this, the cupola and minarets are still in many parts covered with a green lacquered tile, and the great architrave is formed of a dark blue one.

In 1475 was built the painted mosque, in the now ruined city of Gour, in India: it derived its name from the profusion of glazed tiles with which it was ornamented; specimens of which, from the East India Museum, are now before you.

The Mother of Shah Abbas, about 1550, built a caravanserai at Mayar, near Ispahan, the front of the principal gate of which is inlaid with green tiles; and at present the domes of the mosques of that city are covered with green and blue tiles.

The art of covering baked earthenware with an opaque vitreous glaze is said to have been brought from Spain into Italy; and Florence and its territory soon became celebrated for the fine works executed on plates of this ware, which met with a ready sale through Europe. The name given in France to these works was *faience,* supposed to have been derived from Faenza, a village near Florence, or perhaps the word is a mere corruption of Firenze, the Italian name of that city. Tiraboschi mentions one "Luca della Robbia, a Florentine, born in 1388, who appears to have been the first who made figures of terra cotta, and covered them with a varnish, to preserve them from the injuries of time and weather. He

also adorned flat surfaces of terra cotta with various colours, and painted figures on them, by which he rendered himself so famous that he received orders for them from all parts of Europe."

Another artist, of the same name as the preceding, and possibly a descendant of his, is described by Vasari, (*Vite de' Pittori*, lib. i. p. 202,) as having been introduced by Raffaello to the favour of Leo X. He is stated to have carried to high perfection an art long practised by his ancestors, that of painting on *terra invitriata* (glazed earth). In this manner he executed the *impressa* or arms of Leo X., which yet adorn the apartments of the Vatican.

Raffaello himself is said in his youth to have painted, or at least to have given designs for painting, in enamel on glazed earthenware. Such works are commonly known by the name of Raphael china, two interesting specimens of which, from the collection of R. H. Solly, Esq. are now before you. From some casual flaws in the back of these plates, it may be seen that the body of them is red earthenware in one, and grayish brown in the other, and of rather a coarse quality. Mr. Windus also has sent a plate, doubtless of Italian manufacture, bearing the date of 1533, thirteen years after the death of Raffaello.

Mr. Brockedon informs me that, in his journey among the Alps last year, he saw some beautiful specimens of Raphael china, in the possession of the hostess of an inn at the village of Rauris, in Carinthia. They consisted of three dishes: the subjects painted on them are, Pan and Apollo, Jupiter and

Semele, and on the largest, Apollo surrounded by wreaths of nymphs and satyrs, and on the rim are entwined Cupids: this latter dish is about twenty inches in diameter, and bears an inscription, in Italian, purporting that it was made at Rome, in 1542, in the manufactory of Guido di Merlingho Vassaro, a native of Urbino. The date is twenty-two years after the death of Raffaello; but, as the manufacturer was a fellow-townsman of that celebrated artist, the inscription, taken in connexion with the anecdote of Vassari already mentioned, is interesting, as throwing light on the association of the name of Raffaello with this species of ware.

Whether a less ornamented or plain variety of glazed pottery was at this time made in Italy for common table service, I do not know. It is probably from Italy that Holland received this art. The Venetians, the Genoese, and the Florentines, had very extensive commercial dealings with the merchants of Antwerp and of other towns in the Low Countries; it is therefore extremely likely that the potters of Holland, to whom is due the first fabrication of clay tobacco-pipes of excellent quality, derived their knowledge of glazed ware from this source. The town of Delft was the centre of these potteries, in which were fabricated the tiles known in England by the name of Dutch: and the delft ware was employed for table service and for other domestic purposes. Considered merely with regard to its material, the Dutch potters seem to have improved on their Italian originals, being probably instigated by

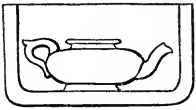
a comparison with the blue and white patterns of Nankin, which was now largely imported by the Dutch from China and Japan, and which is a coarse, yellowish, porcelain body, covered by an opaque white glaze. In the ornamental part, however, the Dutch fell immeasurably short of the potters of Florence: blue and brown seem to have been the only colours employed by them; and their favourite patterns appear to have been either copies of the Chinese, or European and Scripture subjects treated in a truly Chinese manner and taste.

It is about two hundred years ago since some Dutch potters came and established themselves in Lambeth, and by degrees a little colony was fixed in that village, possessed of about twenty manufactories, in which were made the glazed pottery and tiles consumed in London and in various other parts of the kingdom. Here they continued in a flourishing state, giving employment to many hands in the various departments of their art, till about fifty or sixty years ago; when the potters of Staffordshire, by their commercial activity, and by the great improvements introduced by them in the quality of their ware, so completely beat out of the market the Lambeth delft manufacturers, that this ware is now made only by a single house, and forms the smallest part even of their business. Mr. Wisker, a member of the Society, is the potter to whom I allude, and from his liberality I have derived the specimens and details of the manufacture, which I shall now proceed to lay before you.

Those articles of delft ware for which there still continues to be an effective demand, are plain white tiles for dairies and for lining baths, pomatum pots, and a few jugs and other similar articles of a pale blue colour.

The material employed is calcareous clay, or marl, of a blue, red, or yellow colour, from the neighbourhood of Maidstone. The first process which it undergoes is that of grinding with water, and passing it in this state through fine sieves in order to separate the coarser particles. The excess of water is then dried off by exposing the fine mud to spontaneous evaporation in shallow tanks or pits. While still in a soft state it is beat up by hand, and then heaped up in a cave or clay cellar (as it is technically called) till wanted. The longer it remains here, the more tenacious and plastic it becomes. It is then tempered for use by passing it through a pug-mill, or is kneaded by treading; the addition of sand of every kind being carefully avoided. The ware is formed in the usual way, then dried, and afterwards placed in the arch of the kiln to burn into biscuit. It is now of a pale buff colour, the lime in the clay having combined with the oxide of iron, and thus preventing it from exhibiting the red colour which is natural to it, and which it possesses when combined with sand or with mere clay. The glaze is thus formed: Kelp and Woolwich sand are calcined together under the kiln till they combine into a spongy imperfect glass or frit; lead and tin are calcined together till they form a grayish white powdery oxide called by the

potters tin and lead ashes; the frit is then ground dry and afterwards mixed with the ashes, a little zaffre being added if a blue tint is required, and arsenic if the glaze is intended to be white. The composition being well mixed dry, is put in the hottest part of the kiln, where it runs into a vitreous opaque enamel. This latter is then ground under a heavy runner of iron, and is finally mixed with water and rubbed between stones to the consistence of cream. The biscuit, rendered bibulous by drying, is then dipped in this cream, and a sufficient quantity of glaze adheres to the surface of it. The ware is next dried, packed into saggars, which are open boxes of clay, of which the annexed figure is a section, to prevent it from being injured by the smoke; and these saggars are piled in the kiln, so that the bottom of one forms the cover of that on which it rests. A heat moderate for the first twelve hours, and stronger for the last twelve, is applied, which vitrifies the glaze on the surface of the ware, and thus completes the process.



As the use of delft pottery was superseded by the earthenware of Staffordshire, it might seem more natural for me to pass to the description of this latter, rather than to the subject of porcelain. But the European imitations of the Chinese porcelain have introduced so many modifications in the manufacture of the finer kinds of earthenware, that the line of distinction between them has become almost evanes-

cent; and I think it will conduce to the clearer understanding of that part of my subject which yet remains to be illustrated, if I begin with the porcelain of China.

The name China, by which the ware that I am about to describe is known in England, shows sufficiently the country from which we have received it. The term porcelain, which is applied to it on the continent of Europe, is Italian; *porcellana* being in that language the name of those univalve shells forming the genus *cypræa* of the conchologist, which have a high-arched back like that of the hog (*porco*, Ital.), and are remarkable for the white, smooth, vitreous glossiness of the surface about the mouth of the shell, and sometimes, as in the common cowry (*Cypræa moneta*), over the whole surface.

The introduction of the Chinese porcelain a few years before the close of the sixteenth century soon excited a strong desire in the various countries of Europe to imitate it; but as the establishment of experimental manufactories for this purpose required the expenditure of considerable sums, and at a risk beyond the means of private persons, it is chiefly to the munificence of the sovereigns of Europe that the public are indebted for the first steps made in this interesting art. In Germany, chemists and mineralogists were set to work; the latter to seek for the most appropriate raw materials, and the former to purify and to combine them in the most advantageous proportions. The French government adopted the very sensible plan of instructing some of the Jesuit

missionaries, who at that time had penetrated to the court of China, and into most of the provinces of that empire, to collect on the spot specimens of the materials employed by the Chinese themselves, together with the particulars of the process. The precise result thus obtained is not known; for as a considerable rivalry existed between the different royal manufactories of this ware, the most valuable information would of course be kept as secret as possible. The most detailed account hitherto given to the public is that collected by the Père d'Entrecolles, and printed in the *Arts et Métiers* of the Royal Academy of Paris, of which the following is an abstract.

There are three materials employed in forming the body of the ware, but all the three are never used at once.

The first is called *petuntse:* it contains scattered shining particles, is fine grained, and is quarried from certain rocks. It is prepared for use by first breaking it with hammers, then grinding it in mortars with iron pestles, and lastly, is washed over, taking only the white creamy matter that floats on the surface, which, after being dried and pressed into small cakes, is fit for use.

The second material is called *kaolin,* and appears to be porcelain clay, namely, that which results from the decomposition of felspar. It is described as occurring in lumps in the clefts of mountains, covered with a reddish earth. It is prepared for use exactly in the same manner as the *petuntse.*

The third material is called *hoaché;* it is used in-

stead of *kaolin*. It has a smooth soapy feel, and no doubt is either steatite, or soapstone, or agalmatolite. It is prepared in the same manner as the preceding. Porcelain made with this latter is much dearer than that made with *kaolin*. It has an exceedingly fine grain, and is very light but, at the same time, more fragile, and it is not easy to hit on the precise degree of heat that suits it. For the finest porcelain, four parts of *hoaché* are added to one of *petuntse*. Sometimes the body of the ware is made with *kaolin*; and then the article, when dry, is dipped in the *hoaché*, brought to the consistence of cream: what adheres forms a thin layer, on which, when dry, are laid the colours and the glaze; and thus a porcelain finer than the common is obtained. *Hoaché* is also laid with a pencil, before glazing, on those parts of the common porcelain that are intended to have an ivory white colour.

For the fine *kaolin* porcelains, equal parts of that substance and of *petuntse* are employed; for the less fine, two parts of the former and three of the latter. The ingredients being put together in due proportions, the mass is carefully tempered and kneaded by hand, and then the ware is wrought on the wheel, or, for articles of irregular figure which cannot be thus formed, is made by pressing the composition into moulds, and then uniting the several pieces by moist clay. The piece being formed is very carefully dried, and is then covered with the glaze. The white semi-transparent glaze is thus prepared. The whitest *petuntse* with green spots is pulverised and washed

over, as already described; and to one hundred parts of the cream thus obtained are added one part of *che-kao* (burnt alum, or perhaps gypsum) previously pulverised. A caustic potash ley is also prepared, into which *che-kao* is stirred, and the cream thus produced is collected. The two creams are then mixed together in the proportions of ten measures of the former to one of the latter. This composition it is which gives to porcelain glaze its whiteness and lustre.

A brown glaze is made of common yellow clay, washed over and brought to the consistence of cream, and then mixed with the former glaze. If the brown glaze is not to cover the whole of the surface, wet paper is laid on the reserved parts, which, after the glaze has been put on and has ceased to be fluid, is removed, and such blank parts are then painted in colours and covered with the common white glaze.

When the glaze is thoroughly dry, the ware is put into the furnace for the first time; whence it appears that the ware is never in the state of biscuit; a circumstance in which the process materially differs from that adopted by, I believe, all the European manufacturers, who never put on the glaze till after the first firing of the ware.

The flux used with those colours that are laid on over the glaze is made of quartz, calcined and pulverised, and then mixed with cerusse in the proportion of one of quartz to two of cerusse.

Red is given by peroxide of iron, produced by calci-

ning green vitriol; and a finer red is made of copper, but the particular process is kept secret.

The enamel colours are tempered to the proper consistence by a solution of glue, except those into the composition of which the cerusse enters; these latter are tempered only with water.

Such, in few words, is nearly all that is publicly known of the manufacture of porcelain in China, except the mode of packing the ware in saggars previous to firing, and certain other mechanical details not likely to be of general interest.

On the preceding description I have a few remarks to make.

There seems no doubt that the *petuntse* is felspar either pure or mixed with quartz, for the *kaolin* or porcelain clay is incapable, even by the utmost heat of a kiln, of undergoing that commencement of fusion which gives to porcelain its semi-transparency and peculiar texture. Felspar, even that which is naturally of a pale flesh colour, melts at a high heat into a milk white enamel, and from the considerable proportion of potash which it contains (from ten to twelve per cent.), is capable of bearing a mixture of burnt alum or of precipitated alumina, without destroying its fusibility and consequently its utility as a glaze.

But felspar ground to the finest powder requires a considerable time, or free exposure to the air, before any decomposition takes place, and till this occurs it acquires no plasticity. The advantage of keeping the materials of delft ware for a length of time after they

have been duly mixed has already been noticed; and no doubt some of the excellence of China porcelain depends on the perfect plasticity of the material, and the minute division of its particles. We may, therefore, give full credit to the statement, by more than one traveller in China, that for the thinnest and finest porcelain the materials are kept for thirty years or more before they are used.*

All the Chinese porcelains that I have had an opportunity of examining may be reduced to three kinds, as far as regards the body of the ware. The first is that of which the larger pieces of the old blue and white Nankin are formed. Its texture is in general compact, with more or less tendency to fine granular; the fracture surface is even, with a glistening, somewhat resinous lustre; it is translucent at the

* "Of this place," (the city of Tin-gui,) "there is nothing farther to be observed than that cups or bowls or dishes of porcelain ware are there manufactured. The process was explained to me as follows. They collect a certain kind of earth, as it were from a mine, and, laying it in a great heap, suffer it to be exposed to the wind the rain and the sun for thirty or forty years, during which time it is never disturbed. By this it becomes refined and fit for being wrought into the vessels above mentioned. Such colours as may be thought proper are then laid on, and the ware is afterwards baked in ovens or furnaces. Those persons, therefore, who cause the earth to be dug, collect it for their children and grand-children. Great quantities of the manufacture are sold in the city; and for a Venetian groat you may purchase eight porcelain cups."—*Marsden's Marco Polo*, p. 560. Marco Polo was in the service of Kublai Khan, the conqueror of China, from 1274 to 1291.

edges, and has a very pale ochre yellow colour. In order to conceal the colour, it is covered with a white semi-opaque glaze of considerable thickness.

The second differs from the former in having a more compact texture and a white colour. Its glaze is therefore thin and transparent, or nearly so. When the inner surface is left white, as in coffee-cups and other articles of domestic use, no glaze seems to have been applied on that side, it being of itself sufficiently smooth and glossy.

The third kind is lighter than the preceding; it is translucent, has a beautifully even shining surface, but the glaze is so thin as to be scarcely perceptible: it is made only into small articles, and seems to answer well to the *hoaché* porcelain of D'Entrecolles. All the above varieties are exceedingly infusible, being decidedly superior in this quality to most of the European kinds.

For the specimens on the table we are indebted to Mr. Copland and to Mr. Sidney, members of the Society, the former of whom made his collection of porcelain at Canton. The larger pieces are from the collection of H. R. H. the Duke of Sussex, our president: they were brought to England by Lord Macartney, on his return from his embassy to the court of Pekin.

Of the European manufactories of porcelain, that established at Miessen near Dresden, by Augustus Elector of Saxony and King of Poland, in the early part of the 17th century, was the first that aspired to a competition with the Chinese. In compactness

of texture and infusibility it was reckoned perfect a hundred years ago. It is not quite so white as some of the French and English porcelains, but is inferior to none in its painting, gilding, and other decorations. The figures in white biscuit of this ware now before you, belong to a friend of mine who procured them at Dresden; and the other specimens form part of a set presented to your secretary by the King of Saxony.

The French royal manufactory at Sèvres, near Paris, has been for several years in a gradually advancing state, with regard to the whiteness compactness and infusibility of the body, the elegance of the forms, the brilliancy of the colours, the elaborateness of the drawing, and the superb enrichments of the gilding. The private manufactories of porcelain in France imitate and approach more or less near to the royal establishment. Specimens of French porcelain in biscuit, in plain white glazed, and painted and gilded, are now before you, through the kindness of Mr. Windus Mr. Pellatt and Mr. Lemann, members of the Society.

At Berlin and at Vienna are royal porcelain manufactories in high esteem, as well as in some of the smaller states of Germany. For a fine specimen from Hammer, in Bohemia, the Society is indebted to one of its members, Mr. Morrison.

Advantage has recently been taken of the semi-transparency of porcelain biscuit to form it into plates, and to delineate on it some very beautiful copies of landscapes and other drawings, by so adapting the various thicknesses of the plate as to produce, when

held between the eye and the light, the effects of light and shadow in common drawings. The invention originated in the ingenuity of our French neighbours; and some very fine specimens have been sent for exhibition by Mr. Brady.

The first manufactories of porcelain in England were those at Bow, and at Chelsea, near London. I am not aware that the composition of the Dresden porcelain has been divulged; but the liberality of the French government has allowed at different times the publication of much valuable information respecting the composition of the porcelain made at the Royal manufactory at Sèvres, from which, as well as from some other sources, the following particulars have been obtained.

Alumina and silica are the two principal ingredients; but, as mixtures of these two earths in any proportion are incapable of undergoing, by furnace heat, that approach to fusion which produces the texture and transparency characteristic of porcelain, it is necessary to add to them some alkaline substance. The substances actually employed for this purpose are potash, soda, lime, and magnesia, either singly or variously combined.

Of porcelain there are two kinds, the hard and the soft, of which the former alone resembles that of China and Japan. It is considerably less fusible than the soft kind, and therefore requires a higher heat in the burning; it admits of a thinner glaze, and neither the body nor glaze is liable to crack on the sudden application of hot water.

The aluminous ingredient of hard porcelain is that variety of clay called by the English porcelain or Cornish clay, and by the French kaolin, to indicate its identity with the porcelain clay of China.

This clay exists as a constituent of certain grey granites, of which the other component parts are quartz and mica; it therefore represents the felspar of common granite, and in all probability is this very substance in a state of decomposition. Fully crystallized transparent felspar consists, according to Vauquelin's analysis, of 64 silica, 20 alumina, 2 lime, and 14 potash. Decomposed felspar, according to the same able chemist, contains the silica alumina and lime of the original mineral, but the potash is wholly wanting, having probably been washed out by rain water percolating through the rotten granite; and in consequence, the alumina, being no longer in combination with the other ingredients, has acquired a degree of plasticity more or less perfect in proportion to the disintegration of the felspar. The kaolin of Saint Yrieix, near Limoges, which is that employed at Sèvres, contains, according to Berthier, 46·8 silica, 37·3 alumina, 2·5 potash. The kaolin of Schneeberg, in Saxony, which is used in the Dresden porcelain, contains, according to the chemist just mentioned, 43·6 silica, 37·7 alumina, but no potash. The kaolin of St. Stephen's, in Cornwall, which is employed in the English porcelain works, has not been analysed, but from the elaborate method of washing over, by which it is separated from the quartz and mica, it

may be inferred that it retains little, if any, undecomposed felspar, and probably no potash.

M. Dumas has published the composition of three varieties of hard French porcelain, two of which are from the manufactory at Sèvres and the third is made at Paris. Of the two former, that which is employed for table service is composed of 64 parts washed kaolin, 6 chalk of Bougival nearly a pure carbonate of lime, 20 sand of Aumont a very pure quartz sand, 10 petit sable, which is the fine sand obtained in washing over the kaolin, and of which 90 parts when dry contain 80 silica, 8 alumina, and 2·5 potash; it therefore consists of quartz-sand and undecomposed felspar.

The ingredients of the porcelain which is made into ornamental articles are, 62 washed kaolin, 4 chalk of Bougival, 17 quartzy felspar, which is itself composed of about 73 silica, 16 alumina, and 8·5 potash. The porcelain of Sèvres, according to the same chemist, after it has been once through the oven and has passed to the state of biscuit, consists of 59·6 silica, 35 alumina, 1·8 potash, 2·4 lime, 0·8 water.

The glaze employed at Sèvres for both kinds of porcelain is nothing but the quartzy felspar just mentioned, ground to the finest possible powder, and then made into a cream with water and a little vinegar, the use of which latter appears to be that of keeping the earthy particles somewhat longer suspended than they would remain in mere water.

Hard porcelain may also be made by substituting

magnesia for potash. Of this kind is the hoaché of the Chinese (already described), that of Worcester and of Piedmont. Of these latter the composition of the paste before firing (exclusive of water) is, according to Berthier,

Worcest.	Piedm.	
77	60	Silica.
8·6	9	Alumina.
1·2	1·6	Lime.
7	15·2	Magnesia.
93·8	85·8	

It is said, I believe on good authority, that the magnesian ingredient in the Worcester porcelain is derived from the use of the Cornish soapstone: if so, and if the analysis of this latter by Klaproth be considered as correct, the proportion of soapstone to the other ingredients is about 30 per cent.

Soft porcelain is more fusible than the hard, requires a lead glaze, and is liable to crack when exposed suddenly to the action of hot water. The first imitations of Chinese porcelain were of this kind. The ware from the manufactories of Bow and Chelsea near London, was composed of Dorsetshire or Devonshire white clay, and fine and white sand from Alum Bay in the Isle of Wight, to which such a proportion of pounded glass was added as, without causing the ware to soften so as to lose its form, would give it when exposed to a full red heat a semi-transparency, resembling that of the fine porcelain of China.

The soft porcelain made at Sèvres, up to the year 1791, was composed of 21·7 nitre, 7·2 common salt,

3·7 Alicant soda, 3·7 Roman alum, 3·7 calcined gypsum, and 60 quartz sand from Fontainbleau. These ingredients were heated in an oven till they became a semi-vitrified frit; this was then reduced to fine powder, and to six parts of it were added one of chalk and one of calcareous clay from Argenteuil.

The porcelain that is chiefly used by the restaurateurs of Paris is of the soft kind, and is made at Tournay. Its composition, according to M. Berthier, is 75·3 silica, 8·2 alumina, 5·9 soda, 10 lime.

The ironstone china of the English potteries is also a soft porcelain, the composition of which is said to be 42 decomposing felspar, 42 Devonshire clay, 10 calcined flint, 8 flint glass. Two other receipts for this ware give—

300	—	175	Cornish stone.
250	—	150	Porcelain clay.
200	—	90	Blue or brown clay.
100	—	35	Calcined flint.
		5	Frit.
1	—	0·5	Oxide of cobalt.

Of late years burnt bones have been employed by the English potters as an ingredient in soft porcelain, to an amount, it is said, of nearly one half of the whole mass. Such are the following—

360	—	400	Burnt bones.
230	—	300	Porcelain clay.
50	—	250	Cornish stone.
20	—	20	Flint.
0·5	—	0·5	Oxide of Cobalt.
20	—	0	Blue or brown clay.
10	—	0	Frit.

The white figures and cameos of the early Wedgewood ware are also made of a kind of soft porcelain, called white body, or jasper, the composition of which is said to be as follows,—10 native sulphate of barytes, 10 blue clay, 5 burnt bones, 2 flint; and when intended to be blue, a proper quantity of oxide of cobalt was added.

The grinding and due mixture of the ingredients, in order to obtain a mass sufficiently plastic; the forming this mass on the wheel; the subsequent drying of the ware; the first firing, by which it is brought to the state of biscuit; the application of the firmer colours occasionally on the surface of the biscuit; the dipping the biscuit in the glaze; the second firing, by which the glaze is vitrified; the pencilling in of the more tender colours on the surface of the glaze; and the third and last firing that is given to the porcelain,—so nearly resemble the same processes as applied to the more elaborate kinds of earthenware, that it would be a mere anticipation of these latter if I were to describe them now.

Of the English porcelain works, those at Bow and Chelsea were the earliest, those at Derby came, I believe, the next in date; then those at Worcester, established in 1751. More modern manufactories are those of Coalport in Shropshire, of the neighbourhood of Newcastle in Staffordshire, &c.

It is not for me to determine which of our English porcelains is the best; probably, indeed, one will be found superior in hardness, another in whiteness, a third in the thinness and evenness of the glaze, a

fourth in the form of the articles, a fifth in the design, and a sixth in the colours. In hardness and infusibility, they are probably inferior to the Dresden and to the Sèvres porcelain; for pieces in biscuit and in white glaze, from both these manufactories, are imported in considerable quantities, in order to be painted and finished here. But it is equally certain, that the last ten years have seen the commencement, and, in part, the completion of such improvements in this fabric as may, perhaps, place the English porcelains on an equality with the best of the continental European ones.

For the specimens of English porcelain now exhibited, the Society are indebted to the liberality of Mr. Pellatt, Mr. Rose, and Mr. Davenport.

I now proceed to the last division of my subject, namely, the manufacture of those species of glazed pottery known by the general name of Staffordshire ware.

The date of this ware is about sixty years ago, and it unquestionably originated with the late Mr. Wedgewood. It not only originated with him, but was carried by his knowledge, his skill, and his perseverance, to a degree of excellence which, in several points, has never been surpassed, and in some has never been equalled. With a liberal ambition far above the mere love of gain, his ruling object was to carry the art that he practised to the utmost perfection of which it was capable. For this he spared neither time, nor labour, nor expense; and his splendid success, inciting others to follow in the same track,

has secured to his country a most important branch of internal and foreign commerce, and has placed his name for ever among the worthies of the British nation.

He perceived that the defects of the delft ware, at that time the only species of pottery employed for common domestic purposes, were the softness and looseness of texture of its body, which obliged the potter to make it thick and clumsy and heavy, in order to ensure to it a moderate durability; and that its porousness, as well as its dirty gray colour, required a thick coating of white enamel, which added still farther to its bulk and weight, and which, containing a large proportion both of lead and arsenic, was hardly safe for culinary use.

He began, therefore, by inventing a body for earthenware, which at the same time should be white, and capable of enduring a very high degree of heat without fusion, well knowing that the hardness of the ware depended on the high firing to which it has been subjected. For this purpose, rejecting the common clays of his neighbourhood, he sent as far as Dorsetshire and Devonshire for the whiter and purer pipe-clays of those counties. For the siliceous ingredient of his composition he made choice of chalk-flints, calcined and ground to powder.

It might be supposed that white sand would have answered his purpose equally well, and have been cheaper; but, being determined to give the body of his ware as great a degree of compactness as possible, it was necessary that the materials should be re-

duced to the state almost of an impalpable powder; and calcined flints are much more easily brought to this state by grinding than sand would be. The perfect and equable mixture of these two ingredients being a point of great importance, he did not choose to trust merely to the ordinary mode of treading them together when moist, but having ground them between stones separately with water to the consistence of cream, he mixed them together in this state by measure, and then, evaporating the superfluous water by boiling in large cisterns, he obtained a composition of the most perfect uniformity in every part. By the combination of these and other ingredients, in different proportions and exposed to different degrees of heat, he obtained all the variety of texture required, from the bibulous ware employed for glazed articles, such as common plates and dishes, to the compact ware not requiring glazing, of which he made mortars and other similar articles. The almost infusible nature of the body allowed him also to employ a thinner and less fusible glaze, that is, one in which no more lead entered than in common flint glass, and therefore incapable of being affected by any articles of food contained or prepared in such vessels. With these materials, either in their natural white or variously coloured — black by manganese, blue by cobalt, brown and buff by iron — he produced imitations of the Etruscan vases, and of various other works of ancient art, such as the world had never before seen — such as no subsequent artist has ever attempted to rival. His copies of the Portland vase, of which the liberality of Mr. Pellatt enables me to

lay before you a faultless specimen, are miracles of skill, and the other specimens of similar works, for the exhibition of most of which you are indebted to Mr. Josiah Wedgewood, his son and successor, may give some idea of the many beautiful works that were produced in his manufactory.

In table ware, for many years he led the way almost without a rival; but the immense demand occasioned by the successive improvements of this article, which first put down the use of delft, and then of pewter, gave ample room and encouragement to men of capital and skill to enter the field of profit and competition. Much good has hence resulted: many subordinate improvements have been effected and are almost daily making: but it is to be regretted that many of the most modern ones have reference rather to cheapening the price than improving the quality of the ware or even keeping it up to the original standard.

I shall conclude by a summary account of the manufacture of the best table ware; for a considerable part of which I am indebted to notes taken by Captain Bagnold, when visiting a pottery, inferior, perhaps, to none in the country. For the copious and interesting collection of specimens of almost every variety of Staffordshire table ware, we are under great obligation to Mr. Pellatt and Mr. Davenport.

The materials of the Staffordshire ware are calcined flints and clay. The flints are burnt in kilns, and then, while hot, quenched in water, by which they are cracked through their whole substance. After

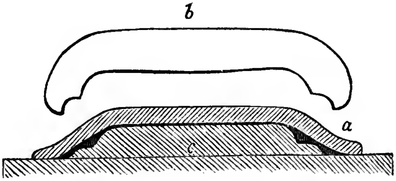
being quenched they are ground in mills with water. The mill is a hollow cylinder of wooden staves bound with hoops, and having a bottom of blocks of chert, a hard, tough, siliceous stone: the mill-shaft is perpendicular, and has two horizontal arms passing through it cross-wise just above the bottom. Between these arms are laid loose blocks of chert, which are moved round on the bed-stone as the arms revolve, and thus grind the flint with water to the consistence of cream.

The clay, from Dorsetshire and Devonshire, is mixed with water, and in this state, as well as the flint, is passed through fine sieves to separate the grosser particles. The flint and clay are now mixed by measure, and the mud or cream is passed again through a sieve in order to render the mixture more complete.

In this state it is called slip, and is now evaporated to a proper consistence in long brick troughs. It is then tempered in the pug-mill, and is now ready for use. Cups, pots, basins, and other round articles, are turned rough on the horizontal potter's wheel, and, when half dried, are again turned in a lathe. They are then fully dried in a stove, and the remaining roughnesses are afterwards removed by friction with coarse paper. Articles that are not round, and the round ones that have embossed designs on their surface, are made of thin sheets of clay rolled out like dough, and then pressed into moulds of plaster of Paris; the moulds being previously dried, absorb the superficial moisture of the clay, and thus allow it to

part from them without injury. The two or three separate pieces composing the article are then united by means of fluid slip. Spouts and handles of jugs and tea-pots are made and united with the body of the vessel in the same way. Small handles, beadings, mouldings, &c. are formed by means of an iron cylinder, having its bottom perforated so as to mould the clay, as it passes through, into the required figure. A piston is inserted into the top of the cylinder, and caused to descend slowly by means of a screw, in consequence of which the clay is continually passing out through the perforation, and is cut off in lengths.

To form a plate, a lump of clay is beaten or rolled into a flat cake, which is then laid on a mould turned to the shape of the upper surface of the plate. A rotatory motion is given to the mould, and an earthenware tool representing a section of the bottom of the plate is pressed on it; thus the plate is made smooth, has a uniform thickness given to it, and it takes a perfect cast of the mould. In the annexed diagram *a* is the clay, *b* the tool that produces the upper surface, and *c* the mould which produces the under surface. Cups, saucers, and basins, when rough-turned, are dried on the block to prevent them from warping.



The ware being thoroughly dried, is packed into saggars and burnt in the kiln to biscuit. Patterns for flat, or nearly flat surfaces, are put on by printing the pattern from a copper-plate with an ink composed of oxide of cobalt, oxide of iron, or other colouring matter, mixed with oil. The impression is taken on tissue paper, and is applied without drying to the surface of the biscuit, and slightly rubbed to make the print adhere: the biscuit is then soaked in water till the paper may be stripped off, leaving the print or pattern behind.* The ware is then dipped in the glaze, which is a mixture of flint slip and white lead, and the bibulous quality of the biscuit causes a sufficient quantity to adhere: the piece is then dried and again passed into the furnace, which brings out the colours of the pattern, and at the same time vitrifies the glaze.

The finest patterns for curved surfaces are applied after the glazing has been completed, by taking the impressions from the copper-plate on a flexible strap covered with a strong gelatinous mixture of glue and treacle. This strap is then pressed on the ware, and gives the impression in glue, the colouring powder is then dusted over it, and a sufficient portion adheres to the damp parts to give the pattern, after having been again in the kiln. The more elaborate patterns on earthenware, and all those on porcelain, are finished by pencilling in.

* This very ingenious method of transferring printed patterns to biscuit ware was invented at the porcelain works at Worcester.

NOTE ON MURRA.

The learned Jos. Scaliger, who was appointed Professor at the University of Leyden in 1593, has published it as his opinion, that the murrine cups mentioned by several Roman writers of the Augustan age, and somewhat later, were Chinese porcelain. Salmasius, a critic of considerable reputation, has adopted the opinion of Scaliger, which has also been maintained by the late Dr. Vincent in his Commentary on the Periplus of the Erythræan Sea, as well as by other learned men. It is therefore worth while to examine the foundation on which this opinion rests.

The only detailed description of murra is in Pliny's Natural History, 37th Book. He there states, that murrine vessels were first brought to Rome among the other gems and precious articles which decorated the third triumph of Pompey the Great, for his victories over the pirates and his conquest of Pontus and Asia. Unwrought masses of murra, and cups made of it, (lapides et pocula ex eo,) were dedicated by Pompey in the temple of the Capitoline Jupiter. It soon passed from sacred to profane use, slabs and vessels for table service being made of it. Murra comes from the East; it is found in several parts of the Parthian territory, but especially in Carmania: its surface never exceeds that of a small slab, and its thickness is rarely so great as that of a drinking cup. Its lustre is without much brilliancy, but it is chiefly valuable for its play of colours, its spots passing from purple into white and a colour composed of both these with a fiery tint or milky redness. Certain parts reflect variable light, like the hues of the rainbow. Any pale or transparent parts are considered as imperfections. It possesses also a certain odour, which is not unpleasant. The demand for this luxury increased so rapidly that for a cup capable of holding three sextarii (4½ pints) were given seventy talents (13,510*l.*) T. Petronius, a consular man, broke before his death a murrine dish valued at three hundred talents that it might not come into the possession of the Emperor Nero. It is considered as originating from some liquid condensed by subterranean heat, as rock crystal originates from some liquid condensed by intense cold.

Such is the description of this substance by Pliny. But the first author who mentions it is Propertius, a contemporary and personal friend of Ovid. In one of his poems he has the following line,—

> Murreaque in Parthis pocula cocta focis,
> iv. 5. 26.

"and murrine cups baked in Parthian furnaces,"—which is the only authority for considering them as a species of earthenware or porcelain, and which character would suit them equally well if they were made not of porcelain but of enamel.

Two of the particulars in Pliny's description are mentioned or alluded to in two of Martial's epigrams, namely, that murra is not transparent, and that it has a certain odour,—

> Nos bibimus vitro, tu murrâ, Pontice, quare?
> Prodat perspicuus ne duo vina calix.
> iv. 85.

> Si calidum potas, ardenti murra Falerno
> Convenit, et melior fit sapor inde mero.
> xiv. 113.

Respecting the rank which it held among other precious articles of luxury it is not necessary to refer to more than two authorities, namely, Juvenal and Suetonius. The former has the lines—

> Grandia tolluntur Crystallina, maxima rursus
> Murrina, deinde Adamas notissimus.
> ii. 6. 154.

The latter states that Augustus Cæsar, on the capture of Alexandria, retained for himself no part of the royal table service except a single murrine cup.* From this passage it may be inferred, that murra was known and highly esteemed by the sovereigns of Egypt.

Against the opinion that murra was Chinese porcelain may be placed the direct statement of Pliny, that it is a natural mineral production, and its iridescent play of colours: and, perhaps, a still more conclusive argument may be drawn from the well-known

* Alexandriâ captâ, nihil sibi, præter unum murrinum calicem, ex instrumento regio, retinuerit.

fact, that at this very time there were two commercial routes open by which the Roman empire was supplied with commodities from the farthest East. One of these was the route by land from the countries north of the Himalaya mountains to Bochara, and thence through the passes into the valley of the Indus. At Ozené, the present Ougein, the commodities were conveyed on board vessels to Barbariké at the mouth of the river, where they were trans-shipped on board the regular traders up the Red Sea to Egypt. Among the exports from Barbariké are sapphire (probably lapis lazuli), onyx stones, and *μυῤῥινὴ*. The other route was wholly by sea; the native traders from Ceylon and the countries beyond came west to Baraké, the present Nelcunda in Malabar, where they disposed of their cargoes to the Roman, Greek, and Egyptian merchants. One of the articles, according to the Periplus, was Seric cloths (*οθόνια σηρικὰ*), that is, manufactured silks; and Cosmas says, that the Tzinistæ (Chinese) bring by sea to Ceylon silk and sandal-wood; but there is no mention of murra or murrine vessels being brought by this route, which, however, would be the cheapest and most direct for any Chinese commodities, especially so bulky an one as porcelain.

At Diospolis in Egypt, according to Arrian, was a manufactory of vessels of murra, in imitation of the genuine ones,* which, together with Indian steel, were sent from Egypt down the Red Sea to Adulis in Abyssinia. Now, Egypt was never at any time celebrated for its pottery; but, before its conquest by the Romans, and long afterwards, was distinguished for the beauty of its glass and enamel. Hence, I think, we may conclude that murra was a mineral substance,—perhaps the gem called cats-eye, or one of the iridescent varieties of Adularia, known among jewellers by the names of sun-stone and moon-stone, and that it was capable of being imitated more or less perfectly in coloured glass or enamel.

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* Fit et tincturæ genere obsidianum ad escaria varia vasa, et totum rubens vitrum atque non translucens hæmatinon adpellatum. Fit et album et *murrinum*, aut hyacinthos sapphirosque imitatum et omnibus aliis coloribus.—*Plin. Hist. Nat.* xxxvi. 67.

II. ON LIMESTONE AND CALCAREOUS CEMENTS.

When men began to assemble themselves in society, and to occupy fixed habitations, the first great work on which to employ their common exertions would be, surrounding the space covered by their huts by a mound or wall, in order to keep out wild beasts and their still more dangerous human enemies. With this view, the most favourable situation that could be chosen would be a detached rocky hill, of moderate height, flat-topped, and having its flanks more or less protected by inaccessible precipices. On the more gently sloping sides a wall would be raised by collecting the largest blocks lying about, and laying them on one another; at the same time so adapting their irregular surfaces as to leave between them the least possible spaces, and filling up these spaces with smaller pieces of stone. Walls of this kind, if skilfully built, and with blocks of large dimensions, even if not united into one mass by the use of cement, oppose, by the mere magnitude and weight of their ingredients, great impediments to disintegration, either from natural causes or external violence. If the hill thus occupied

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were massive in its structure, like granite or basalt, the blocks furnished by it would be of very indeterminate figures, and the face of the wall would present the appearance of irregular polygons, which would require, on the part of the builders, considerable skill to arrange without interstices. But, if the hill were composed of beds or strata, lying over one another, then the blocks would offer at least two parallel faces, and thus would be far more easy to arrange as a wall. Examples of this very antique mode of building, generally known by the name of Cyclopean, are by no means unfrequent in Greece and in Italy, especially in that part of it formerly called Etruria. Mycene, in Peloponnesus, is very remarkable for its gateway and walls of Cyclopean architecture, which we know to have resisted the utmost efforts of the Argians to demolish, at the time they took the city, and have since, for a long series of centuries, continued to brave the destructive rage of barbarians and of the elements. Even in more regular and elaborate structures of hewn stone, where the blocks are large, and the surfaces of pressure well levelled, the use of cement may be dispensed with, as is the case in the antique temples of Upper Egypt.

But where, from choice or necessity, the materials of building are pieces of small size, whether regular or irregular in figure, it is impossible to make of them solid and durable constructions without the use of cement of some kind interposed between the pieces, in order to bind them together. Every one who has travelled through the hilly districts of this country, must have

observed the dry stone walls by which the fields are inclosed, and probably have personally experienced the ease with which a breach may be made, even in those that are the most carefully and solidly built. We know, from the concurrence of sacred and profane history, that one of the earliest seats of the human race was the alluvial plain watered and periodically inundated by the Euphrates. In this district neither rocky strata nor detached blocks of stone are to be found, but a tenacious and silty soil offers to the ingenuity of man materials capable of being moulded into artificial stone, that is, bricks, of any desirable form. It is impossible to make bricks of very large dimensions, as the clay would infallibly crack in drying, as well as in baking. While, therefore, we learn from historical authority that the structures of ancient Babylon were raised in brick, we know, from the testimony of modern travellers, who have examined the ruins, that these bricks are not more than about 13 inches square by about three inches thick. From this fact we might infallibly conclude, even in the absence of all direct evidence, that cement of some sort must have been employed in raising walls and other solid buildings of such materials. Bitumen, in a melted state, was, as we are informed by Herodotus, and by the author of the book of Genesis, the substance made use of on this occasion; and this statement is confirmed by recent observers, who inform us not only that at Hit, a district a little higher up the river than the ruins of Babylon, there are even now numerous springs of petroleum; but that those parts

of the ruins themselves which seem to be the oldest, are constructed of layers of unburnt brick, faced by layers of burnt ones; the whole cemented together by bitumen and mats made of reeds. But the knowledge and use of calcareous cements was either contemporary with that of bitumen, or was invented shortly after; for, among these very ruins occur many parts built of burnt brick set in lime-mortar, which latter, even at the present day, is of extreme toughness and hardness.

But no ancient people seem to have made so much use of calcareous cements as the Romans, for, with the exception of the cloaca maxima, or great sewer — a subterranean vaulted tunnel, constructed, according to tradition, in the reign of their king Tarquinius Superbus, of blocks of a light and porous stone, without any cement whatever — with the exception, I say, of this great work, all the other public structures appear to have been of brick or stone, cemented by lime-mortar. Nor was it in raising buildings alone, in the usual acceptation of the term, that calcareous cements were employed by the Romans; the chief of their military roads and highways were pavements resting on a foundation of rough stones consolidated into one mass by liquid mortar or grout, which, beginning at Rome itself, accompanied and facilitated the march of her conquering legions to the very remotest extremities of the empire. The port of Ostia, at the mouth of the Tiber, was a place of immense consequence, as commanding the whole water communication of the capital with the provinces, and great

exertions were made, by the construction of moles and jetties, to convert the naturally hazardous and exposed entrance of the river into a secure and capacious harbour. The fashion, also, among the more opulent classes, of quitting Rome during the heats of summer, for a residence in the numerous villas on the shores of the bays of Naples and Baiæ, and which were frequently constructed on moles actually projecting into the sea, rendered necessary the invention of a cement capable of preserving its efficacy even under water. Accident or experiment, discovered near the town of Puteoli (itself situated on the bay of Baiæ) a bed of porous, half concreted matter, which, when reduced to powder and mixed with lime or with common mortar, gave to it the property of hardening under water. The substance described by Vitruvius and by Pliny, by the name of powder of Puteoli (Pulvis Puteolanus), still retains essentially the same appellation; only, as the name of the town has been modernized into Pozzuoli, so that of the substance has passed into that of puzzolana.

If the description given by Julius Cæsar of the towns in the south-eastern part of Britain, which, from its vicinity to the continent of Europe was also the most civilized, be at all correct, it is highly probable that the use of calcareous cements was not known in this country till after its conquest by the Romans. Of the buildings erected by them the greater part have now perished from the effects of time and of violence; but some of the simpler kinds still remain sufficiently entire to show their style of

building, and the durability of their materials. The most ancient limestone quarries in the kingdom, and which continue still in full activity, were originally opened by the Romans, at Tadcaster, in Yorkshire, the name of which place in the Roman itineraries is, from this circumstance, called Calcariæ.

The gothic style of architecture, with its intricacy and elaborateness of parts and its richness and multiplicity of ornament, being scarcely consistent with the use of large blocks of stone, rendered necessary the copious employment of mortar. The facility of construction hence arising has in many instances tempted the builder to take up with stone of inferior quality, the chief dependence for the strength and durability of his work being placed on the tough cement by which these, otherwise inadequate, materials have been consolidated.

The essential ingredient of all calcareous cements is lime, a substance which never occurs naturally in a pure state, being always combined with some other body, as well as mechanically mixed with impurities of various kinds. The usual state in which it is found is as an earthy salt, called, when crystallized, calcareous spar; and, when massive, limestone, being combined with carbonic acid in the proportion of about 54 of lime to 46 of carbonic acid in the 100 parts.

The natural state of carbonic acid, under the ordinary atmospheric pressure and temperature, is a gas, or permanently elastic fluid; and as this gas is but sparingly soluble in water, it follows that when we

put a piece of limestone in a glass, and cover it with water, and then add any substance capable, by combining with the lime, of separating the carbonic acid, this latter will rise through the water in a stream of bubbles, producing that appearance which the chemist calls effervescence. Most acids, when dissolved in water, will separate carbonic acid from lime in the way I have just described; and hence we are furnished with an easy test for distinguishing limestone from sandstone and from other usually occurring rocks, by its almost entire solubility, accompanied by effervescence, in cold dilute muriatic or nitric acid; the proportion that remains undissolved indicating with considerable, though not perfect, accuracy, the amount of impurities.

Every kind of limestone is not equally adapted to the use of the builder; and, as these differences depend partly on mechanical and partly on chemical properties, it becomes necessary to describe somewhat in detail the principal varieties of limestone, as far as their economical use is thereby affected. With this view they may conveniently be arranged into four families.

The first includes those limestones which are, for the most part, of a pale colour, and burn to a white lime, containing very little foreign matter.

Of these, the purest is white granular or statuary marble, which contains hardly any impurities except a little siliceous earth. This is actually used by the chemist when he wants a lime purer than usual; but as, when heated, it is very liable, on account of its

granular crystalline structure, to fall into a coarse powder, it is manifestly incapable of being burnt in a common limekiln, and therefore is of no use as a material for mortar.

White chalk is another of this family, which, on account of its softness and porousness, is easily quarried, and requires less fuel and a shorter time for its burning than common gray limestone does. It has however this disadvantage, namely, that the cores or centres of those pieces that have been only superficially burnt are easily broken down with the back of a spade, and therefore are often mixed up with the other ingredients of the mortar, instead of being scrupulously rejected, as they ought to be.

Oolite is another limestone of this family, and derives its name from the small round grains or concretions of which it is principally composed, and which were formerly supposed to be the eggs of fish in a petrified state. In hardness and other qualities, it holds a place intermediate between chalk and gray limestone.

Gray limestone itself includes all those beds in mountain limestone and in transition limestone which, with a structure passing from scaly into compact, are decidedly harder than the preceding, and require the assistance of gunpowder to detach them from the quarry, unless where they occur in very thin beds. They take, in burning, a longer time and somewhat greater quantity of fuel than the preceding, and are often mere aggregates of corals and other organic remains. The amount of impurity, chiefly sand and

clay, rarely exceeds four or five per cent., and the darker varieties usually furnish the whitest lime, showing the colour to be chiefly carbonaceous.

The second family includes the swinestones and bituminous limestones; the first name being given to them from the fetid smell, like that of a hogstye, produced by rubbing them against any hard substance. Their colour is dark brown passing into black, all the varieties of black marble being of this kind. When heated red hot, the carbonaceous colouring matter begins to re-act on the carbonic acid, converts it into another gas called carbonic oxide, which having no attraction for lime, flies off, leaving behind the lime itself, of a snow-white colour, and rendered perfectly caustic, in a shorter time and by a less expenditure of fuel, than is required for any other kind of limestone. Being, when burnt, more porous than any other of the compact limestones, it falls down into an exceedingly fine powder by the action of water, or on exposure to the air; a quality which renders it particularly valuable to the farmer as well as to the builder.

The third family is that of the magnesian limestones. Its chief repository in this country is that very extensive formation called the new red sandstone, which, in the natural series, lies immediately above the coal measures: here it occurs in thick beds, as well as occasionally in the mountain limestone. Its colour is sometimes reddish, but usually is of a pale yellowish brown. Many varieties have so greatly the aspect of fine grained sandstone that they were for a long time

considered as such; but a minute inspection will show that they are an aggregate of small rhomboidal crystals, which on analysis prove to be compounds of carbonate of lime and carbonate of magnesia, the relative proportions of which, though subject to considerable variation, may be stated at about three-fifths carbonate of lime, and two-fifths carbonate of magnesia. If a piece of this limestone be put into cold dilute nitric acid, it will dissolve very slowly with hardly any sensible effervescence, although in hot acid the effervescence will be as vigorous as with common limestone. When burnt to lime, it retains its causticity for a much longer period than common lime does; and, therefore, no doubt modifies to a certain degree the properties of the mortar into the composition of which it enters, although its precise action has hitherto been very little investigated.

The proportion of sand that magnesian lime requires to make good mortar seems to depend wholly on the lime and not at all on the magnesia, so that 100 parts of a limestone containing 20 per cent. of this latter earth, will admit of no more sand than 80 parts of purely calcareous limestone will.

The fourth and last family includes those limestones which contain in their composition so large a proportion of iron and clay as to enable them to form cements, which have the property of becoming solid under water, and, therefore, are peculiarly valuable in subaqueous constructions; and are for this reason often called hydraulic limestones.

One of these is the gray chalk, or chalk-marl.

The bottom bed of the great deposit of chalk is considerably thicker than the upper ones, and contains no flints; in colour it is of a less pure white or gray, and is considerably harder than the upper chalk, so that many parts of it make a tolerably good building stone. In composition it is not uniform; the proportion of slightly ferruginous clay that it contains notably increasing from the top to the bottom of the bed: the lower parts moulder by exposure to weather; and the lowest of all not only moulder, but are more or less slaty in structure; that is, are in the state of true marl. That part of the gray chalk which is used for water cement, contains various proportions of clay, from 6 or 8 up to about 25 per cent. and after burning has a pale brownish yellow colour. It is known in the London market by the name of Dorking lime, there being very extensive quarries of it near that town, as well as at Merstham and Halling.

Another and still more valuable variety of limestone for water cement, is the blue limestone, which is generally of a dark dove colour, and of a dull earthy aspect: by long exposure to weather it becomes, superficially at least, of a liver brown, and when burnt into lime is of a buff colour. It forms occasional beds in the transition and mountain limestone deposits, but constitutes nearly the whole of the lias limestone. This latter is one of the most remarkable of the English strata. Its geological position is between the lower oolite, and the new red sandstone. It passes obliquely through the country in a direction

from N.E. to S.W.; from the sea coast at Whitby, to the cliffs at Lyme-Regis in Dorsetshire on the British channel. In its course southward it passes to the east of York, and crosses the Humber near the junction of the Trent and Ouse; thence it passes through the western edge of Lincolnshire, and traverses the counties of Nottingham, Leicester, Warwick, and Gloucester; its breadth in this part of its course being pretty uniformly about six miles. Hence, the main body proceeds in nearly a southerly direction through Somersetshire to the coast of Dorset, while a broken line of the same skirts along the southern shore of the Bristol channel as far as Watchet, and appears on the northern shore in detached patches in the counties of Monmouth and Glamorgan. The entire thickness of this deposit is perhaps about 250 feet; the middle part consists of beds of blue limestone alternating with blackish slaty marl; the upper and lower parts being less calcareous than the middle, are composed chiefly of beds of marl, in which are harder masses of a compressed globular figure, less clayey than the slaty marl in which they are found, but less calcareous than the blue limestone. The quarries of Watchet, Aberthaw, and Barrow in Leicestershire, were long celebrated for the excellent water lime which they produce, before it had been ascertained from geological surveys that they are in fact on different parts of the same deposit. From an analysis by Mr. Smeaton of the blue limestone of Watchet, Aberthaw, and Bath, the proportion of iron and clay in each appears to be the same, or about

11¼ per cent. The blue lime of Barrow, according to Mr. Marshall, contains about 14, and according to Smeaton 21·3 per cent. of the same ingredient, and that of Westbury, 9 per cent. The lias limestone used by the London builders is brought from Lyme-Regis, but is little used in the metropolis, being about 25 per cent. dearer than Dorking lime, the difference in cost depending, in part at least, on the longer time and greater quantity of fuel required in burning it.

The balls which I have mentioned as occurring in the upper and lower beds of the lias formation, are not peculiar to it, but appear to be formed in all deposits of bluish slaty clay that contain carbonate of lime, but not sufficient to separate from the rest of the ingredients into distinct beds of limestone. Thus, in several of the beds of blue clay that lie above the chalk in that district called the London Basin, are to be found layers of compressed spheroidal balls, known by the name of septaria, or cement stone. The outer part of them consists of obscurely slaty concentric layers, with an excess of clay, and which peel off by long exposure to the air; the interior part is more compact, and is not unfrequently divided into nearly cubical pieces by cracks generally filled or lined with calcareous spar. They may be observed in the cliffs of London clay that form the eastern coast of the island of Sheppy, also in the low cliff at Southend at the mouth of the Thames; and they have been dug up wherever excavations have been made in the London clay, as at the archway road at

Highgate, and in the deep cutting and tunnelling now going on (in 1835) for the London and Birmingham railway, near Primrose Hill. Of late years these stones, burnt and reduced to powder, have been very extensively used in all water building and other masonry requiring particular care, with such success as to have entirely superseded the employment of puzzolana and of Dutch tarras. With this concludes my survey of the calcareous raw materials employed in the construction of cements, in which I have begun from the purest kinds of limestone and have terminated with those that contain the smallest proportions of carbonate of lime.

Two other sorts of materials now require a short notice. The first comprehends a few non-calcareous substances, the essential ingredients of which appear to be oxide of iron and burnt clay, which have the power of giving to mortar made of white lime the property of becoming extraordinarily hard and of setting under water.

Of these, puzzolana is volcanic ashes thrown out of Vesuvius during its eruptions, and concreted on the places where it has fallen, into a cellular mass of a rusty colour and of slight cohesion.

Tarras, or trass, is a bluish black cellular trap or lava, quarried at Andernach on the Rhine into millstones; the fragments produced in making which are sent to Holland, where they are ground into powder; and when mixed with lias lime form a cement, extensively used in the dykes and other water buildings of that country.

In England, Rowley rag, a basalt obtained from the Rowley Hills in Warwickshire and in composition probably very similar to the Andernach stone, has been used for the same purposes with good effect.

The other non-calcareous ingredient employed in the composition of mortar is sand, which, with reference to this use of it, may be divided into the pure and the clayey, the coarse and fine-grained, the round and the sharp-angled. Smeaton has shown by actual experiment, that raw clay sensibly impairs the hardness of mortar; it is obvious, therefore, that the use of pit-sand, which is generally dirty, should be avoided where it is possible, unless it has been previously cleaned by washing till it no longer troubles the clearness of the water. As the action of sand in mortar seems to be, for the most part at least, mechanical, that which is sharp-angled is evidently better than that which is round, as offering a better surface for the adhesion of the lime; it is likewise manifest that a due admixture of coarse and fine sand will fill a space, leaving the smallest interstices, and, therefore, capable of greater resistance to external pressure. Where chalybeate springs rise out of sand, the colour of this latter is yellow from the intermixture of ochre; and such sands, if free from clay and used soon after they have been dug, produce a cement of extraordinary hardness.

Limestone, even when reduced to the finest powder, is wholly inefficacious in the composition of mortar, and it is only useful for this purpose when the carbonic acid has been driven off from it by a high heat

continued a sufficient length of time. The fetid limestones, as I have already mentioned, may be wholly deprived of their carbonic acid at a lower heat than is required for the other limestones. In these latter it is probable that no difference in intensity of heat is required, but a longer continuance of it, according as the limestone under operation is more or less clayey, and more or less compact. The separation of the carbonic acid begins from the outside of the pieces, and so proceeds to the centre. The size, therefore, of the pieces before burning should be equal and as small as is consistent with the expense of breaking them. It may easily be judged whether a kiln of limestone has been perfectly burnt by taking a few samples, and selecting a piece as big as a pea from the middle of each, and then dropping them separately into a glass containing weak muriatic acid. If no effervescence ensues, the burning has been complete, and the degree of its incompleteness may be estimated by the vigour of the effervescence as compared with that of an equal piece of the same limestone unburnt.

As soon as the lime has grown cold, it begins to reabsorb carbonic acid; and, in course of time, will fall to pieces and return to the state of carbonate; there is, therefore, an obvious advantage in using lime as soon as possible after it has been burnt; a considerable difference, however, occurs in the rate at which different limes recover their carbonic acid, the white limes take it up the most rapidly, and the argillaceous and magnesian ones the most slowly. In an experiment by Mr. Marshall, a piece of white Bristol lime,

kept in a drawer, was found, in seven days, to have increased in weight thirty-three per cent.; while a piece of blue lias lime from Westbury, in the same time, and in the same place, had increased no more than ten and a half per cent.* In close casks, the lias lime will keep good for a long time. Smeaton's experience goes as far as seven years; but, in this case, the lime was previously reduced to powder by slacking with water, and then was trodden hard down into the casks.

When cold water is poured on a piece of perfectly well-burnt lime, it is rapidly absorbed and in great abundance; the piece becomes warm, then cracks, gets hotter than the hand can bear, exhales a large quantity of steam, and finally falls down into a dry powder almost as fine and impalpable as flour. To appearance, the whole of the water is evaporated; but the great heat produced shows that very energetic chemical action has taken place; and on weighing the lime, it will be found to have increased in weight 24·2 per cent., which increase is nothing but water combined with the lime into a solid substance, and which no heat short of redness will entirely separate from it. This compound is called hydrate of lime or slacked lime; and it is this, and not lime itself, which enters into the composition of mortar. Lime, retaining its carbonic acid, will not combine with water; and, therefore, those pieces that are

* Probably, however, the increase of weight in both these instances is due in part to the absorption of moisture as well as carbonic acid from the air.

very imperfectly burnt remain as lumps or cores after the rest has fallen to powder; and the mortar is all the better for their exclusion.

By the addition of a little water, hydrate of lime may be made into a stiff paste, which, in a short time will become dry and will retain its form, although it possesses scarcely any hardness or tenacity, and a shower of rain will wash it all away. It is only by the admixture of sand and other hard substances that it acquires the properties of a mortar or cement. The proportion of sand that can be incorporated into mortar depends partly on the fineness or coarseness of the sand itself, and partly on the nature of the lime; but, as the sand is the cheaper ingredient, there is always a temptation to excess on this side. Pliny mentions that the failure of buildings at Rome in his time was owing to a deficiency of lime in the mortar: the proper portions being 1 of lime to 4 of sharp pit-sand, and 1 of lime to 3 of round-grained sand from the sea or river: he likewise adds, that the quality of the mortar is greatly improved by the addition of a third part of pounded tiles. The common London mortar is made of 1 part white chalk lime and $2\frac{1}{2}$ of clean sharp river sand; but, not unfrequently, dirty pit sand is substituted for the latter, and, the lime itself being very imperfectly burnt, a mixture is the result which never becomes hard and has only a very imperfect adhesion to the bricks. White lime when really good, will take a larger proportion of sand than the brown limes will, but, in the London practice, the reverse generally prevails;

an additional proof of the badness of common chalk lime. Although it be certain that lime has a considerable chemical attraction for silica in a state of solution, or, perhaps, of very fine division, yet it seems improbable that any action should exist between the two when the silica is in grains of sand, especially considering their hardness and, consequently, the strong adhesion between the particles of which they are composed; yet there are certain facts and points of practice which can hardly be explained, unless this be admitted. The cohesion of a paste of hydrate of lime is not greater than that of a paste of carbonate of lime or chalk, and if the action of sand were merely mechanical, it is not easy to understand why it should form with hydrate of lime a strong cement, and not with chalk. It was an ancient law in Rome, that after the ingredients of mortar had been rubbed together with a little water, the mass should be kept in a covered pit for three years before being used; and we are expressly informed by Pliny that buildings erected during the operation of that law were not liable to cracks. It was likewise an ancient practice (and Smeaton has confirmed the advantage of it by his own experience) to beat the mortar for a long time with a heavy pestle just before being used; the effect of which would be, not only more thoroughly to mix the ingredients, but to rub off from the outside of the grains of sand the compound of lime and silica, if such had been formed, and, by incorporating it with the mass, dispose it the more rapidly to consolidate. Mr. Smeaton also found that mortar made with white

lime, is far more improved by repeated beating than cement formed of argillo-ferruginous lime, which is satisfactorily accounted for by assuming (and it may be done with great probability) that the combination of part of the lime with the clay is effected in these latter limestones during the process of burning. The same excellent observer also found that if two samples —one of well-beaten mortar and the other of mortar mixed only in the usual way—be afterwards diluted with water to the state of grout, the former will set sooner and become harder than the latter, which is all in favour of chemical action taking place between the ingredients. This combination of lime and silica (perhaps, I ought only to say this *supposed* combination) appears, however, to be decomposable by the carbonic acid of the atmosphere, just as silicate of potash is; for, by long exposure, the lime in mortar will regain the greater part, but, probably, not the whole of its original carbonic acid. Thus Mr. Tennant found that common mortar which had been exposed to the air for a year and three quarters, had regained only 63 per cent. of its full quantity of carbonic acid; and Mr. Marshall found that some mortar from Pickering Castle, some centuries old, had regained not more than 86 per cent. of its carbonic acid. I may also mention, as having some relation to this question, that many attempts have been made to burn old mortar, with the expectation of bringing it again into a state capable of forming a cement when mixed with water, but without the smallest success.

Of water cements there is a great variety, both as

relates to the ingredients themselves and their composition; some of the principal of which I shall now proceed to notice.

The only cement employed by the Roman builders in the erection of moles and other structures in the sea, was 1 of lime, and 2 of puzzolana. Mr. Smeaton's cement, which he employed in building the Eddystone Lighthouse, was, equal measures of Aberthaw lime in the state of hydrate and in fine powder, and of puzzolana also in fine powder; proportions which, if reduced to weight and due allowance be made for 24 per cent. of water in the lime, differ not materially from those recommended by Vitruvius. The cement was also well beaten till it had acquired its utmost degree of toughness, and, probably, therefore, till chemical action had begun to take place.

The gray chalk of Dorking forms the basis of a number of excellent cements, for use both in water and on land. The composition of that which is most generally used is 1 of lime to 3 or $3\frac{1}{2}$ of sharp river sand; and for filling-in the interstices of thick walls, 1 of lime to 4 of coarse gravelly sand.

The piece of brick-work now exhibited is part of the boundary wall of the East India Dock, built in 1804, and taken down in 1834. It was cut off a large block, carried away on a truck, and afterwards chiselled into shape, without the cement giving way in the slightest degree. It was composed of 1 part Merstham lime and 4 parts gravelly sand dug out of the excavation of the dock; and if this sand was, like that dug out of the London Docks, deeply coloured

with yellow ochre, the extraordinary goodness of it is very satisfactorily accounted for, and it differs from two other specimens before you only in the circumstance that the former of these contains 2 of the same kind of sand, and the other 5.

To the same class of cements belong a specimen composed of 1 lime, and $3\frac{1}{2}$ sand dredged out of the Thames, and two concretes or pebble mortars; the former of which is composed of 1 lime and 7 river ballast, and the latter of 1 lime and 8 clean-washed shingle.

Tarras mortar, made of white lime and tarras, requires long and repeated beatings to bring it to perfection; probably, in consequence of the tarras not having previously been roasted. And the evidence of chemical action among the ingredients of this cement is unquestionable, by its *growing*, as the workmen call it, in the joints of the masonry, owing, no doubt, to the expansion of the tarras in proportion as it is acted on by the lime.

In the cements made with lias or argillo-ferruginous limestone, the clay and oxide of iron seem to have combined with the lime during the burning, forming a compound capable of uniting with great firmness, and without much difficulty, with an additional portion of sand or of burnt ferruginous clay; the quantity of this latter admissible into the cement being probably the less, as the amount of the same in the lime itself is the greater. Lias is but little used in London, on account of the greater cheapness of yellow chalk which answers nearly the same purpose but is not so

strong. It was, however, employed in the cement used for setting the bricks that form the facing of the London Docks, to the depth of 14 or 18 inches from the outside. The precise composition of the cement was—

4	Lias lime.
6	River sand.
1	Puzzolana.
1	Calcined iron stone.
12	

The celebrated ash-mortar, or *cendrée* of Tournay, may be mentioned as, perhaps, the best of the lias cements. It is thus prepared. After the large pieces of lias are withdrawn from the kiln, there remain a quantity of small fragments, mixed with the ashes of the very slaty coal which is the fuel employed in the average proportion of 3 of ashes and 1 of lime. Of this mixture, about a bushel at a time is taken, and is sprinkled with water only sufficient to slack the lime; the whole quantity thus treated is then put into a pit and covered with earth, where it remains for some weeks. It is then taken out, and well beaten by an iron pestle for half an hour which brings it to the consistence of soft mortar; it is then laid in the shade for a day or two to dry and again beaten till it becomes soft. This is repeated three or four times till at length it is only just sufficiently soft for use; being then applied to brick or stone, it forms in a few minutes a very compact mass and after twenty-four hours has acquired a stony hardness.

The process and its effects are well worthy of notice. The coal-ash is chiefly burnt clay in a state of fine division, and therefore well fitted to combine rapidly with the argillo-ferruginous lime. By bringing the lime to the state of hydrate and allowing it to remain for some time in contact with the ash, a commencement of combination in all probability takes place; this is carried farther by the process of beating, during which the lime parts with its water and combines with the ash; and, when by a continuance of this process no increase of moisture is produced, it may be presumed that nearly perfect combination of the lime and ash has happened, and the cement is then ready to set and become solid.

I have already explained what the balls are of which Roman cement is formed, namely, a limestone more highly charged with ferruginous clay than even lias limestone; so that they may, without impropriety, be considered as containing not only the calcareous ingredient but the ferruginous clay also required for the composition of cement. On this account it is that, when burnt, so little of their lime is in a state to become hydrate, that, though when moistened with water the mass will heat, it will not fall to powder but requires to be ground, and, when afterwards beaten, it will form a hard cement without any further addition. It is, however, capable of combining into a firm mortar with a considerable proportion of sand, either alone or mixed with yellow chalk lime, which considerably reduces the cost and at the same time produces an excellent cement, either

for land or water building. The cement stones are prepared for use by making a judicious selection of them, breaking them into pieces about two inches cube, stratifying them with coal in a kiln and burning them for several hours. One bushel of coals with careful management, will roast eight bushels of cement. The kiln is kept in constant activity, and the roasted stones are taken immediately from the kiln to a mill where they are ground to powder. This powder is then, without delay, to be packed in tight casks as exposure to the air much weakens it, although it may be kept for many months in an open place without becoming quite effete. The best cement powder when mixed and prepared for use, has a dusky green colour, and I am informed that some of the manufacturers are in the habit of mixing the burnt stone, before grinding, with certain proportions of copper slag, a substance consisting chiefly of sulphuret of iron and oxide of iron, and, therefore, an exceedingly valuable addition if not too liberally employed. The two bricks on the table have been cemented with a compound of 1 yellow lime, and 2½ pulverised copper slag; and I observe, on the surface of the cement a saline efflorescence, which, in stucco and other dry work, might prove detrimental.

Oxide of iron in the state of yellow hydrate, and in general when not fully oxidized, such as smiths' scales roasted iron ore, &c. is also a very useful ingredient, giving firmness and the property of setting under water to mortars made of white lime, and

adding to the peculiar characteristic excellences of those made with brown or yellow lime.

The general theory that seems to me to explain with fewest difficulties the nature of calcareous cements is the following:—

In the white limes or nearly pure carbonates of lime, the only effect of burning them is to drive off the carbonic acid. By slacking, the lime becomes a hydrate and in this state is capable of acting chemically though feebly on the surface of pure siliceous sand. This combination causes the first setting of the mortar, which is also strengthened by the mere mechanical action of the sand. The greater part, however, of the lime has not combined with the sand but remains in the state of hydrate; in proportion as this latter absorbs carbonic acid from the air it gives out its water and passes to the state of carbonate: such mortar, therefore, acquires its final induration and dryness when the whole of the hydrate has been decomposed and the water has been replaced by carbonic acid. In losing 22 per cent. of water it combines with 46 per cent. of carbonic acid, and therefore the mortar becomes the more solid and strong.

In the blue limes, part of the calcareous matter combines during the burning with the silica alumina and oxide of iron constituting the intimately mixed ferruginous clay, forming a compound that gives to the cement made of it the property of setting speedily in the air or under water. The rest of the lime passes, by slacking, into the state of hydrate; and, if only siliceous sand is present, acts on it in the same

manner as white lime does; but if ferruginous sand or burnt ferruginous clay be present, the hydrate acts more rapidly and powerfully on the clay, sooner gives out its water and consolidates: whether this latter compound is afterwards decomposable by exposure to the carbonic acid of the air, I do not presume to determine.

In those limes that contain naturally so much ferruginous clay as, after burning, to form cements without the addition of sand or other ingredient, the greater part of the lime is probably combined with the clay in the act of burning, a very small quantity of hydrate will be formed, and very little carbonic acid will be reabsorbed.

III. ON GYPSUM AND ITS USES.

Gypsum, called by chemists sulphate of lime, is a compound of sulphuric acid, lime, and water, in the proportion of about 46·5 of the first, 32·5 of the second and 21· of the third in 100 parts.

It must be carefully distinguished from another sulphate of lime, the anhydrous, so called from its containing no water of crystallization. This latter it is which forms an Italian marble of some value called il Marmo Bardiglio di Bergamo: but in specific gravity and in other physical and chemical properties it differs essentially from gypsum, and especially in the circumstance that it is not capable when calcined of combining with water and forming with it a cement or plaster.

Gypsum is soluble in about 500 parts, by weight, of cold water and is a very frequent ingredient in natural waters, both of springs and rivers. If we take any common water and boil it for a few minutes, then filter it, and evaporate it till it begins to grow turbid, and afterwards add its own bulk of rectified spirit of wine, we shall obtain a precipitate which

after being washed in a few drops of cold distilled water may be considered as the gypsum of the water under examination. Waters holding gypsum in solution belong to the class of hard waters: they have a remarkably flat taste and are said, perhaps from no very accurate experiments, to weaken the digestive power of the stomach. They curdle soap and hence are neither so effectual nor so economical for washing in as the softer waters: they have also the property of modifying the tints of animal and vegetable colours as well as of fixing them in a certain degree in the fibres of cotton and other cloths. On this account it is that those are the most successful in their preparation of carmines lakes and other delicate and brilliant pigments, who use distilled water both in dissolving the ingredients and in washing the precipitates. This probably is also one reason why the same ingredients that at Lyons give to their silks exceedingly brilliant tints have notoriously failed when tried with the gypseous waters of London. The same circumstance likewise it is which in many situations renders it difficult for our calico-printers to clear sufficiently the white grounds of their prints, without having recourse to means which injure the colours of the pattern and perhaps also the strength of the cloth itself. The ancient Greek painters were in the habit of using gypsum tinged with certain colours, probably vegetable, but whether they did so from observing that the colours were thus rendered more durable does not appear.

Gypsum abounds in the blue clay, called by geolo-

gists the London clay, which overspreads the valley of the Thames, from Reading to the Isle of Sheppey. In many parts this clay is covered by sand and gravel which afford large quantities of soft clear water, but all the wells that are sunk into the clay and not through it, afford very scanty supplies of a hard gypseous water. This is particularly the case with the wells on the north of London those namely on the elevated ground on which Hampstead and Highgate are situated, and beyond those hills in the vale of the Brent and on its northern boundary. Also on the N.E. of London, especially the elevated tract forming Henault and Epping Forests and the intervening vale of the Roding. That gypsum is more abundant in the London clay than is generally supposed, though not usually distinguishable from the mere clay by the eye, I have frequently had occasion to observe. The deep cutting at the Highgate archway was in this bed: the clods as they were dug presented the ordinary uniform appearance of the clay; but, after exposure for a year or more to the air and the rain, had become rough with projecting crystals of gypsum from an eighth to a quarter of an inch in length, formed doubtless by the action of the rain on the clay which by dissolving the gypsum enabled it to separate from the other ingredients by the attraction of crystallization.

The beds on which Paris is built and which extend to a considerable distance beyond that centre, being similar in geological position to the London clay and possessing a great number of testaceous organic re-

mains in common with it, are considered to be substantially the same with the great single deposit of the valley of the Thames, but containing a larger proportion of calcareous matter; which consequently, as often happens in similar cases, has detached itself more or less perfectly from the clay with which it would else have been uniformly mixed. These calcareous and gypseous beds are three or four in number and in them the celebrated plaster quarries of Montmartre are opened. The gypsum which they yield is harder, more earthy, less white, than the purer varieties of this substance, and is mixed with about 17 per cent. of carbonate of lime. It is better fitted for cements stuccos and other architectural uses on account of this mixture; but for castings, especially the finer kinds, the Parisian artists themselves have for some time been in the habit of importing the Newark gypsum, as being whiter and affording a finer grained and more compact plaster.

Several other clayey beds in the English series of strata afford gypsum, either intimately mixed with the clay or only separated from it in the state of single crystals or small clusters of them imbedded in and inclosed by the clay; such are, the Weald clay, which contains the Petworth marble and occupies a considerable part of the weald or forest land of Kent Surry and Sussex; a brown clay belonging to the Purbeck series of beds, and in which at Durleston bay a quarry of gypsum is actually worked; also the blue Oxford clay, which at Shotover Hill near that city abounds in crystals of gypsum. But the great repo-

sitory of massive gypsum, as well as of its finer crystallized and fibrous varieties, is that rock which is familiarly known to English geologists by the name of red marl or new red sandstone. This rock is very irregular in its structure and composition, but its upper portion is essentially characterized by its beds of blue and red clay, more or less calcareous and sandy, in which most of our brine springs and all our beds of rock salt occur and are more or less accompanied with gypsum: but this latter mineral is found, perhaps even most abundantly, in those parts of the red marl where no salt has been hitherto discovered. If from Gloucester on the Severn we drew a line N.W. to the mouth of the Dee in Cheshire, and another N.E. curving somewhat to the south, to Whitby on the Yorkshire coast, we shall include within this angle the greater part of the red marl district and the whole of the gypsum quarries, with the exception of that already mentioned in Dorsetshire and one or two small ones that are worked in the red marl of Cumberland. It is on the eastern side of this angle that the principal gypsum quarries occur, because it is here that the beds of this substance come to the surface, or are covered only by a few feet in thickness of red and blue marl. In Derbyshire the most productive quarries of gypsum are at Chellaston on the S.E. of Derby, but the quality of it generally speaking is not very good. The coarser varieties are employed in the neighbourhood for floors of cottages and of farm houses, the better sorts are sent by canal to the potteries of Staffordshire where they are employ-

ed partly as an ingredient of certain kinds of earthenware and porcelain, and partly in making moulds for those articles of pottery that cannot receive their form (whether oval or irregular) on the common wheel. The select pieces of Derbyshire gypsum are reserved for ornamental purposes, being formed, by carving and turning, into vases small statues and other figures, of which there exists a considerable manufacture at the town of Derby. Gypsum when employed in this way generally bears the name of *alabaster*, a Greek word, the derivation of which is not very evident. If, as is commonly supposed, it means "that which cannot be handled," such an appellation must be allowed to be quite appropriate to ornaments made of granular gypsum, which, on account of their softness fragility and purity of colour and the impossibility of removing from them any accidental stain or soil, can be secured uninjured only under glass, the way in which such articles as are of elaborate workmanship are at present preserved.

Gypsum of a quality, generally speaking, superior to that of Derbyshire is dug near Ferrybridge in the south of Yorkshire. But the quarries near Newark in Nottinghamshire are allowed to yield the best, that is, the purest gypsum, and, I believe, London is wholly supplied from this quarter as well as the foreign demand, considerable quantities being sent to Paris, as I have already stated, as well as to Holland Germany and the countries on the Baltic. On the western side of the red marl district the gypsum lies too deep to be raised to any profit, but that it exists

here we well know from the borings and pits that have been sunk in Cheshire and near Droitwich and Stoke-Prior in Worcestershire, for rock salt or brine springs; at Droitwich gypsum was found at the depth of 35 feet, and continued for a thickness of 105 feet, being only divided into two beds by the intervention of a stratum of brine 22 inches deep: immediately below the gypsum was rock salt.

Beds containing both gypsum and rock salt occupy very extensive tracts on the continent of Europe. They overspread the middle and southern districts of European Russia, thence pass into Poland, Transylvania, Upper Austria, Bavaria, Salzburg, the Tyrol, and parts of Switzerland. Gypsum of very fine quality is also abundant in Spain in Italy and Sicily. In Carmania and other parts of the Asiatic Turkish territory it is found, as well as in Persia and in the salt districts of the north of Africa. It is also mentioned by ancient Greek writers as being found in Syria, Phœnicia, the territory of Thurium in Italy, the neighbourhood of Tymphæa and Perhebæa in Greece, and most abundantly in the island of Cyprus.

The crystals of gypsum are generally in the form of more or less compressed rhomboids, which are easily divisible into thin laminæ by splitting them parallel to their two broad planes. Such laminæ were employed at Rome in the reign of Tiberius for many of the purposes that we at present use window-glass. It was, therefore, an object of considerable importance to obtain these plates as large and transparent as possible. Spain and Cappadocia furnished

the best, sometimes of the length of five feet. This variety of gypsum was known by the name of Lapis specularis, from the use to which it was applied, namely, in glazing windows and conservatories in which were placed fruit trees to protect their produce from the winter's cold, and in the construction of bee-hives, as Pliny expressly informs us, for the purpose of enabling the curious to observe the proceedings of these interesting insects. The temple of Fortune at Præneste was built of slabs of gypsum, through which the light came and fell on the statue of the goddess which was placed in the centre of the edifice.

When gypsum has been deprived of its water by exposure to heat and has been reduced to a fine powder, it is capable by mixture with water of being brought to the consistence of a pulp. This pulp in a short time sets or becomes solid, a very sensible degree of heat being given out by the mixture during the act of consolidation. If, therefore, the pulp be poured into a mould it is evident that when it has become solid it will retain the figure of the cavity into which it had been poured. On this fact depends the utility of gypsum as a material for casting and taking impressions. But before I enter into the consideration of this part of my subject with reference to the practice of modern art, it will be neither useless nor uninteresting to ascertain how far the application of gypsum to these purposes was known to the ancients.

Herodotus in his history (III. § 24), states that

Cambyses after his conquest of Egypt sent an embassy into Ethiopia, and that his envoys on their return gave an account, among other things, of the mode in which the Ethiopians disposed of their dead. The body after having been extenuated, probably by drying or by embalming, was coated over with gypsum; the surface of which was painted so as to represent as nearly as possible a portrait of the person inclosed. A block of some kind of transparent stone was then quarried out and hollowed with great labour for the reception of the mummy, so that it could be seen through the transparent coffin in which it was put. Now, however small be the credence that we may choose to give to the report of these envoys,—a report, however, which seems to receive some confirmation from the alabaster soros discovered by Belzoni at Gournon in Upper Egypt, and now in the possession of Mr. Soane, — still it is evident that gypsum and its property of forming a cement were familiar to the Greeks at least as early as the time of the Persian invasion of their country under Xerxes.

Theophrastus, who though younger than Plato and Aristotle was contemporary with them, wrote a history of minerals in which is contained an account of gypsum, from which I have extracted the following particulars. After mentioning that gypsum is found in Greece, in Cyprus, in Phœnicia and in Italy, he distinguishes two kinds the pulverulent and the compact; the latter he considers the best: it is not quarried, says he, in blocks but is got in lumps; it is

then burnt in furnaces and afterwards reduced to powder: when water is added it becomes warm and adhesive, and in this state is used in building when it is required to cement together any parts: it is mixed with water as it is wanted, for it shortly becomes solid and cannot then be broken down for use. It appears to excel all other materials for receiving impressions, to which purpose it is particularly applied in Greece on account of its smoothness and adhesiveness. It is also used by painters and fullers.

It would have been very satisfactory if Theophrastus had particularized the objects of which gypsum was employed to take the impressions; but as he has not done so, the safer way will be to rest satisfied with what he has told us and not to endeavour to supply the deficiency by mere conjecture. In Pliny, however, we have an authority in effect contemporary with Theophrastus; for the 35th Book of his Natural History, which treats of painting and modelling, is an abridged compilation from the works of twenty-six Greek authors of which, unfortunately, the only one that has come down to modern times is the treatise of Theophrastus already mentioned. From Pliny then, or rather from his Greek authorities, we learn that Lysistratus of Sicyon, brother to the celebrated sculptor Lysippus, was the first who aimed at rendering his statues likenesses of those whom he professed to represent. Before his time the aim of the artist had rather been to make a beautiful face than a portrait. Lysistratus endeavoured to con-

ciliate both these advantages by taking a cast in gypsum from the living face and then from this mould a second cast in wax, which, from its ductile quality, allowed him to rectify the imperfection of the plaster mould, and to add as much beauty as was compatible with the preservation of the likeness. This plan succeeded so well that no statues or bas reliefs were afterwards made without a previous model. It does not appear however, with the exception of mere masks, that the Greeks were acquainted with any but those which are technically called waste moulds, that is, with moulds that must be broken in order to get out the casting, and consequently will give only one; for we learn that a certain Roman knight of the name of Octavius, being about to have an ornamented cup made, gave a talent for a plaster model, and that Arcesilaus, a Greek artist the friend of Lucius Lucullus, sold his models even to artists for higher prices than many others could obtain for their finished works. With regard to the application of gypsum to the ornamental parts of architecture, we learn from the same authority that it was employed chiefly in stucco work for wreaths and medallions and similar ornaments of ceilings, cornices, &c. as may at this day be seen in the remains of the Baths of Titus at Rome and in Pompeii.

For the history of plaster-casting in the middle ages I can find no authorities. It probably was little if at all practised. On the revival of art in Italy by Cimabue, Leonardo da Vinci and Michel Angelo, and on the discovery of many precious specimens of

ancient sculpture, the desire of possessing at least true copies of these latter excited the ingenuity of artists to invent a method of moulding from or rather upon them, so as to obtain from such mould an accurate casting in gypsum without material injury to the mould itself. This however presented great difficulties, and it appears to have been but slowly that the art of composing or building up *safe moulds* was completed. The names of Verrochio, Rosso, and Primatice are mentioned by historians as those to whom this art is chiefly indebted; and the effective patronage seems chiefly to have come from the sovereigns of France, Francis the First, Henry the Fourth, and Louis the Fourteenth, who very laudably wished to put the School of Fine Arts at Paris in possession of casts of those immortal works of Greece, the admiration the study and the despair of all succeeding times.

The French artists appear to have attended more than those of any other country except Italy to casting in plaster. A reduced copy of the equestrian statue of Louis XV. by M. Pigalle was moulded by M. Pomel, and is said to have given more than a hundred casts without any sensible injury.

Boetius de Boot of Bruges, physician to the Emperor Rudolph, published his history of gems and stones in 1609 in which is an account of gypsum: and if it is allowable to draw an inference from his silence it might be supposed that the art of casting in plaster had not yet made its way into Germany; for the only application of this substance to the use

of the fine arts that he mentions, is a method of making extremely light colossal statues. He states that a rude imitation of the intended figure is to be made of wool, hay, or tow, which is then to be coated over with liquid plaster and afterwards wrought into form.*

The art of casting in plaster is now well known in all the countries of Europe, but it is still principally practised, at least in England, by natives of Italy. The fine castings that fill the shops of the dealers in such articles are chiefly executed by Italians of a humble class in life but imbued with genuine feeling of the beautiful and true in art, and very dextrous in all the practical manipulations: even the boards of our itinerant dealers in images (to use the popular word) are now filled with casts, by no means ill-executed, of works of high merit, and will no doubt tend to purify the taste of the public by removing from their view the trash which heretofore was vended under the same name.

I now proceed to give some details respecting the practical application of this art; for the most valuable part of which I am indebted to the liberality of Mr. Deville.

* Mr. Wilson in his very interesting paper on the state of the arts in modern Italy (Jameson's Edinburgh new Philosophical Journal for January 1841) in describing the temporary triumphal arches erected on various occasions, says, "the statues are formed of straw arranged round wooden supports; casts of heads hands and feet are easily procured and attached. This *anima* (soul) as it is termed, is skilfully enveloped in drapery of cotton cloth, which is tastefully arranged by an artist, and is then lightly brushed over with whitewash which stiffens it."

The first thing, in the order of time, that requires attention is the due appropriation of the different varieties of gypsum to the uses for which they are best fitted. Much of the gypsum of Montmartre, as well as that of Yorkshire and Derbyshire, contains a considerable quantity of carbonate of lime, and is therefore better fitted for cement to supply the place of mortar, and for outside work in stucco, than for any other purpose. But on this account it must be calcined at a heat sufficient to expel the water of crystallization of the gypsum and also part at least of the carbonic acid of the carbonate of lime.

This is done at Montmartre in kilns built in the open air but protected from rain. The gypsum is quarried in lumps about the size of a large clenched hand and weighing from two to three pounds each. It is stored up for use under a shed, it being considered of great importance that it should go quite dry into the kiln, in order that the proportion of fuel may be duly regulated. The kiln is a space 10 feet long bounded on the two sides and one end by walls of which the latter is the highest. Within this space four or five longitudinal walls are built up of the most regularly shaped lumps of gypsum to the height of the outer side-walls, the intervals are filled up with billet-wood and faggots, and arches of gypsum are built over them with sufficient attention to accuracy of construction that they shall not fall in when the fuel is consumed. An aperture about six inches square is left adjoining the end wall to produce a sufficient draft through the kiln. Over the

whole of the arches or vaulted space thin alternate layers of small charcoal or dry wood and pieces of gypsum are laid to the height of 18 or 20 inches. The kiln being completed, fire is applied at the front of the flues and the heat is kept up by farther supplies of billet-wood for from 24 to about 40 hours, according to the quantity of gypsum and the quality of the fuel, till the calcination is finished.

Cement is made of this gypsum by mixing it with water and with sand, but it is not capable of taking so large a proportion of this latter ingredient as quick-lime will. The cement sets speedily and answers better for stone, the common building material at Paris, than it would for brick.

For making floors the same kind of gypsum is employed, but it is prepared somewhat differently. It is first dried at a very gentle heat, then is pulverized either in hand mortars or in mills and lastly is *boiled;* that is, the powder is put by itself into an iron pot and placed over the fire: those particles which are at the bottom are of course sooner heated than the rest, and their water of crystallization, amounting to 21 per cent. of the whole, is converted to steam, and in escaping through the incumbent mass of powder puts all its particles into motion, not unlike that of a boiling liquid. This motion ceases when all the water is driven off, and the gypsum is then considered to be sufficiently heated, it not being necessary to the solidity or durability of the floor that the carbonic acid also should have been driven off.

For making casts, the purest gypsum is the best; and in works where only a small quantity is required, as in casts of medals, selenite or crystallized gypsum is sometimes employed, but this does not appear to be more free from extraneous matter than the best parts of the crystalline gypsum rock of Newark.

In working in plaster it is of the utmost importance to know accurately the time which it takes in consolidating or setting. Without this knowledge much time would be lost and the work would often prove defective. This uniformity of quality, however, depends on several apparently trifling niceties of practice in preparing the gypsum for use. I consider myself therefore under no small obligations to Mr. Deville for communicating to me the following particulars of the processes employed by a gypsum burner of the name of Rogers, who gave up business about ten years ago. To such perfection in his art had this person attained that different parcels of his plaster would not vary ten seconds in their time of setting during a period of five years or more. The gypsum was procured from Newark, and by special agreement it was quarried in dry weather and stacked under covered sheds previous to being shipped for London. It was conveyed from the ship to Mr. Rogers's premises in decked barges, and every possible care was taken to prevent it from becoming wet. It was next sorted into three qualities. The first or coarsest was of a brown colour and consisted of the outer part of each lump or block, the second was of a dingy or

dirty white and occupied the intermediate part of the block; the third, being the best or finest, was the central part. The calcining ovens, of which there were several on the premises, were of that size called 10 bushel ovens. They were heated by billet-wood till a particular part of the oven was white hot; the gypsum then (being previously reduced to pieces about the size of a hen's egg) was thrown on the floor of the oven to the amount of between 12 and 13 cwts. which it covered to the depth of five or six inches. The door of the oven was then carefully closed and kept in that state for 12 hours. At the end of this time it was opened, but the gypsum remained in the oven for three hours or more afterwards, and being then taken out was removed as soon as possible into covered boxes holding about a firkin each. In these it remained for 16 or 18 hours and was then pulverized in the usual mill for grinding dry articles, namely, an upright stone moving round on a flat bed-stone. The inferior gypsum was then passed through a coarse sieve, and the finest kind being run through a lawn sieve produced a gypsum fit for medal casting and other similar uses.

Gypsum will keep for any length of time uninjured if absolutely excluded from the air, but, as this is impossible on the large scale, it is not wise to accumulate a stock of it: the sooner it is used after grinding and sifting the better is the plaster. An attentive workman can judge of the quality of the powder by taking a handful and squeezing it moderately tight: if but little escapes between the fingers

and on opening the hand again the powder slightly coheres like wheat flour, it is good, but if it directly falls to pieces, it has been injured by damp. For use, it is mixed with water; and the proportion of this latter depends on the purpose to which it is intended to be applied. The more fluid the mixture is the more easily and perfectly will it enter the finest lines of the mould; but such casts when dry are more porous, and therefore more tender, than those in which a smaller quantity of water has been used. Much also depends on properly mixing the ingredients: the water must never be poured on the powder, but the powder must be shaken into the water, and the best way of doing this is to take up the powder between the fingers and thumb and then allow it to drop gradually into the water, taking care that it does not run into lumps and that every parcel becomes thoroughly soaked. Proceed in this way till the powder comes to the level of the water and then stop if a thin plaster is wanted, but, if a stronger one is required, keep adding powder till it stands about a tenth of an inch above the water. When the whole of the gypsum has been put in, allow the ingredients to remain undisturbed for a few seconds, and then stir up the mixture cautiously and gently with a spatula, and as soon as it begins sensibly to thicken pour it into the mould. The great error that amateurs fall into in this part of the process arises from want of patience: they put the powder into the water too hastily, generally employing too much of it and keep incessantly stirring it

till it thickens; the consequence of which is, that it contains air bubbles, is hard in some places and soft in others, and is not capable of being perfectly united to a succeeding layer of plaster. Good plaster, when mixed with the proper quantity of water, should be of the consistence of cream, and will set or become solid in about ten minutes but cannot safely be removed from the mould till about half an hour afterwards.

Plaster made with river water sets sooner by a few seconds than if made with spring water, and therefore in large castings the first tub of plaster should be made with river water and the second with spring water to allow the necessary time for applying them. Hot water will also greatly expedite the setting, but on this account its use is to be carefully avoided in making plaster for castings and for most other purposes. A little common salt dissolved in the water will also hasten the setting; as, on the other hand, a little size or beer or urine mixed with the water will retard the setting for four or five hours, especially the latter. The use however of all these articles is rather to be avoided than encouraged as injuring the quality of the plaster.

The distinction between casts and moulds is not very clear, because in many cases it is merely relative. Thus a plaster mask is a cast of the living or dead face of which it is an impression; but it is a mould with regard to any subsequent casting that may be made in it, as this latter may in its turn become a mould for a secondary mask. Some kinds

of moulds however are made of a number of separate pieces and these are never called casts: the essential character of the compound idea, cast, being that of a coagulable liquid poured on or cast into some substance of which when become solid it retains the impression. With this explanation therefore I proceed to make some observations on moulds.

It is evident that a cast of a mere surface may be had in a single piece and this even when the surface is considerably indented, provided such indentations are all open hollows without any half-covered or under cut or projecting parts. A page of common printing type may be considered as an example of such a surface, and a perfect cast of it in reverse may be had in a single piece by covering it with plaster. Medals, seals, cameos and intaglios are similarly circumstanced; and as many of the ancient gems, as they are called, are very elaborate works of art, a collection of plaster casts of such is both useful to the classical student and agreeable to the amateur and man of taste. I shall therefore give a brief account of medal casting, for which I am indebted to Mr. Kelsall.

The devices on medals and the figures on the engraved gems are projecting or in relief; and as it is desirable that the casts of them should be in relief also, it is evidently necessary that a hollow mould be cast on the original and that a cast in relief be got from the hollow mould. In so doing however we get our cast only at second hand as it were, and, as the execution of the original is very minute

and delicate, great care is requisite lest much of the beauty vanish in the processes necessary to transfer it.

Sulphur is sometimes used as the material of the mould, but to this there are several objections. In the first place it generally crystallizes on cooling and therefore fails to take a perfect impression even when applied to an engraved gem: in the next place if poured on the surface of a medal it is liable to give an indelible stain to it and to adhere; and if with a view of preventing this the medal is previously oiled, a film of oil becomes interposed between the sulphur and the metal and consequently blunts the sharpness of the impression.

Plaster will form an exceedingly good mould as far as the impression is concerned, but in order to prevent the cast from sticking to the mould, it is necessary to saturate this latter with oil and even this method will not always avail. If however the mould, being previously thoroughly dried, is soaked in melted wax and afterwards washed on the surface with a solution of wax in oil of turpentine and then allowed to dry, it will deliver a perfect cast without sticking.

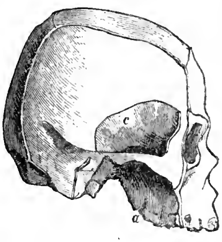
Wax itself however on the whole forms the best mould if treated in the following manner. The medal is to be surrounded with a raised border about half an inch high of thin sheet lead, such as is used to line tea boxes; care being taken to apply it so close to the medal as to prevent the escape of the melted wax. A cup containing white wax is to be put into

another filled with boiling water, and when the wax is thus fused at the lowest possible heat, it is to be poured quickly on the surface of the medal, previously made quite clean and gently warmed. When the wax has set, but before it has cooled, pass the point of a knife horizontally through the lead so as to separate that ring of wax which will have been drawn a little way up the side of the lead by capillary attraction, and this will prevent the mould from cracking, as it sometimes is apt to do if this little manipulation is not attended to. The wax when quite cold is to be gently raised from the surface of the medal, and will be found to have taken a most perfect impression of it. Then surround the wax with a border of thin stiff paper and pour in a little thin plaster made as already described: force this as speedily as possible by means of a camel hair brush into the minutest cavities of the mould and, when it begins to set, pour in more plaster till it reaches the top of the border. In about half an hour the cast may be separated from the mould without any difficulty.

If a mould is to be made from an entire solid substance, how simple so ever the form may be, an egg for example, it is evident that the mould must be in at least two pieces in order in the first place to separate it from the original, and in the next place to be able to get the cast out of it or, to use the technical term, to make it deliver. But if we want a mould from an unyielding hard body which contains any projecting parts or undercut surfaces or

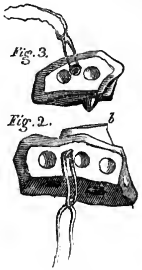
deep irregular hollows, although there is no difficulty in forcing the fluid plaster into these parts, it is manifest that the inverted wedges and dovetails that would be thus formed would wholly prevent the mould from separating from the original. The only way therefore of making a mould from such undercut surfaces, capable of delivering the cast without injury either to itself or to the mould, is to build up the latter of separate pieces; the great art being to have as few pieces as possible, and that these when put together ready to receive the cast, shall interlock so securely as not to move during the process. In order to explain clearly this very ingenious manipulation I must have recourse to the accompanying figures.

Fig. 1.



Let fig. 1, which really represents a cast, be an original scull of which it is required to make a mould. It is evident, if this were put in a box or case and liquid plaster were poured over it, that some of the plaster would run into and fill the cavities *a* and *c* as well as those of the eyes, and that it would be quite impossible to disengage the scull from the cast without breaking one or both. A safe mould of this object is made in the following way. The cavity *a* is first filled with plaster, and as its surface, though irregular, presents no undercut parts, the cast of this separate portion may be removed without difficulty. The

outer surfaces, those, namely, which did not touch and therefore have not received any impression from the original, are to be scraped smooth, and shallow holes or pits are to be cut on them. This piece is shown in fig. 2, the surface representing that part of the original to which it was applied not being seen, with the exception of the projecting part which lay under the arch of the cheek bone, and on the top of which a hole, the mouth of which is seen at *b*, has been cut. This piece thus prepared is to be carefully dried and then soaked with oil. Fig. 2 being now returned to the cavity *a* and filling it, plaster is poured into the cavity *c* and takes an impression not only of this cavity but of the hole at *b* in fig. 2. This second piece is then withdrawn, and, the outer surface being smoothed and having two holes cut in it, is represented in fig. 3, at the base of which may be seen the tooth or prominence which, having been moulded in the cavity *b*, serves in part to lock these two pieces together. The piece fig. 3 being then dried and oiled, the next step in the process is to put the pieces 2 and 3 in their places and to cast over them the plate or piece *d* fig. 5. This piece takes the impression of the outer surfaces of the pieces 2 and 3 which fill respectively the cavities *a* and *c* fig. 1, and also of that part of the scull bounded by the raised lines within



which *a* and *c* are inclosed. The piece *d* does not adhere to 2 and 3 because they have been oiled, but it takes the impression of their holes and thus forms as many corresponding projections or teeth, by means of which the three pieces are securely locked together. The under surface of *d* is shown in fig. 4. The four edges of *d* (including in this the pieces 2 and 3) that touch the pieces *g e k* and *f*, fig. 5, are then smoothed

Fig. 4.

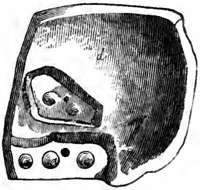
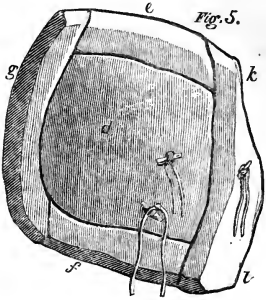
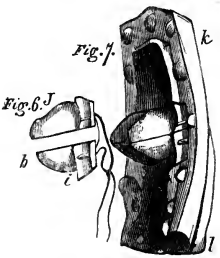


Fig. 5.



and three holes are made in each edge. The processes that I have now minutely described, and in the same order, are used to get moulds of the same parts figs. 2, 3 and 4 on the opposite side of the scull. This being done, the pieces *d d* are put in their places and the piece *e* fig. 5, being the crown of the scull, is formed: on two of its edges by which it touches *d d* are teeth which take into the holes of these latter pieces, and holes are sunk on the other two edges which abut on *g* and *k*. The scull is now turned upside down and the piece *f* fig. 5 is moulded, holes being made on that edge which touches the piece

k l. The next in order is to get moulds of the cavities of the eyes; but owing to the particular form of these parts it is necessary that the mould of each should be made in two pieces: *i* fig. 7 is made first and then *j*, and over these the mask *k l* is cast. Thus the mould of the scull has been made of six large and eight smaller pieces. The next thing to be done is to insert a small staple made of wire into each of the small pieces and to tie a piece of string to it leaving the two ends an inch or two long, as shown in the figures



In *d* fig. 4 are made two holes through which the strings of 2 and 3 are passed; each of these is tied in a loop and a piece of stick is passed through, by turning which round the string is shortened and the pieces are consequently fixed tight in their respective places in *d*, the friction of the stick against the plaster preventing the string from untwisting. The two pieces that fill each eye-hole are adjusted in like manner, two holes being made in the mask or face-piece *k l* to admit the strings. The mould is now complete, and being put together as shown in fig. 5, and farther secured by cord tied round it, is placed base upwards and is filled with plaster which is poured in through a hole in *f* either left during the moulding or cut afterwards. To make the mould deliver, the strings are first to be loosened by taking away the sticks

the mask *k l* is then to be removed, then the pieces *g e f* and *d* in the order now mentioned; next, the pieces 2 and 3, and lastly the pieces *i* and *j*. Fig. 1 represents the cast thus formed, the prominent ridges marking the place of junction of the larger pieces of the mould.

Such a mould as that now described is called a *safe* mould because it may be made to deliver the cast without injury to one or the other by taking it to pieces, and therefore will give any number of perfect casts unless it happens to be accidentally damaged.

Moulds of statues are made in this way and, as Mr. Deville informs me, sometimes consist of 700 or more separate pieces. The ridges on the surface of the cast indicate the principal divisions of the mould.

The plaster being duly mixed is poured into the mould at one two or three runnings according to circumstances. As the impression is received only by the plaster of the first running the finest gypsum is used for this: that for the subsequent runnings is of a coarser kind, being only wanted to strengthen the first. Small castings are sometimes solid, but often hollow; and this is effected by pouring in a small quantity of plaster and then turning the mould about while the plaster is setting that it may adhere only to the face of the mould. Statues and similar large articles are always cast hollow.

A mould, of the head for example, may be made from the living or dead body; but such mould is always run in one piece and is divided into two or three in order to take it off. This may be done,

because though there are some undercut surfaces about the lips and other parts, yet the flesh of which these are composed is pliable and will therefore deliver the mould without injuring it. But such a mould can only give one perfect cast and is therefore called a waste mould, and if a safe mould of the subject is required, the cast must have a safe mould built upon it in the manner already described.

In order to prevent the plaster from adhering to the surface of an original or of a mould, such mould or original is to be smeared over first of all with oil: but, in casting from statues, as oil would soak into the marble and injure its appearance, the usual way is first to brush the marble with white of egg beat up, and when this is dry to brush on a strong solution of soap in water mixed up with a little clay. Moulds, being first carefully dried at a very gentle heat, are then coated with linseed oil which is allowed to harden for at least a week before using.

Attempts have been made to give to plaster casts somewhat of the hardness and lustre of marble, and two methods have been chiefly relied on for this purpose. One is to make a hot saturated solution of common alum in water and to dip the cast in the liquor, repeating the dippings till the cast refuses to absorb any more. When dry it will be found to have acquired from this process a considerable compactness of surface with increased hardness and some degree of semi-transparency. But the solution of alum always dissolves a little of the surface of the cast so

as to injure the perfect truth of it, and the marble appearance thus produced loses much of its beauty after some time. Another and better way of hardening a cast, is to dry it gradually at a moderate heat and then coat it with melted white wax: it is then to be warmed by placing it before the fire till the wax has been absorbed; the cast if thin will now become translucent and is capable of a considerable polish from friction.

There are two other modes of obtaining casts which when carefully and skilfully practised are eminently successful, and therefore require a short notice.

The first of these was invented by Mr. Deeble, for which he obtained a medal from the Society of Arts. His object was to obtain casts of leaves with all their natural and beautiful undulations for the use of the painter or architect. For this purpose the newly gathered leaf, before it becomes flaccid, is to be laid with its face upwards in a natural position on a bed of fine grained moist sand; and then by means of a broad camel's hair brush is to be covered over with a thin coating of wax and Burgundy pitch rendered fluid by a gentle heat. The leaf is now removed from the sand and dipped in cold water, which hardens the wax and allows the leaf to be ripped from it without injuring the impression. This being done the wax mould is to be placed in sand and banked up as the leaf was: it is then covered with thin plaster laid on with a brush and forced into all the interstices of the mould; more plaster is then poured on, and, when it sets, the warmth produced is

enough to render the wax pliable, which with a little dexterity may be rolled up, parting completely from the cast.

The second method was invented by Mr. Fox of Derby for which he received the medal of the Society. The object of this gentleman was to form an elastic mould of only two pieces capable of delivering under-cut surfaces. The body on which the mould is to be formed, being previously oiled, is to be suspended about an inch above the bottom of a box or any other convenient vessel: warm melted glue mixed with a little treacle, and made as thick as possible provided it will run, is to be poured in so as completely to cover the body to be moulded. The glue when cold is to be divided by a sharp knife or in any other convenient way into two parts, and the nucleus or body will without difficulty part from this elastic mould, however tubercular and irregular the surface may be. The two pieces of the mould being oiled are to be bound together with tape, and the cavity being filled in the usual way with plaster affords a perfect cast, as proved by the specimens deposited by Mr. Fox in the Society's museum.

It would be a mere waste of words to demonstrate formally the advantages of plaster casting. By the artist by the amateur by the man of science and in common life it is perpetually called into use. The best thing next to having originals is to have accurate copies of them; and from all solid substances of moderate bulk we obtain copies by casting far more perfect than the pencil of the artist is capable of

delineating; for by one we obtain a fac simile and by the other only a representation in a single position, with this additional advantage on the part of the former, that we are able to multiply copies of it cheaply expeditiously and mechanically.

Gypsum likewise enters as a predominating ingredient into some useful cements. One impenetrable by water and which also is not injured by severe frost is thus prepared. Take scales from a smith's forge and pound them moderately fine, mix them with five times their bulk of plaster, then add water enough to make the whole into a stiff paste; stir it but little and apply it immediately—it will prove as firm as the best Roman cement.

For a cement to fix a joint or to stop a hole in boilers or other machinery not exposed to a temperature higher than 450° Fahr. nothing answers better than the finest plaster and white lead mixed to the consistence of putty. It must at first be kept in its place by tying something round it, and after two or three hours it will have become quite stiff and firm. The only precaution in applying this or the former cement is that all grease of any kind should first be removed.

IV. ON FURS AND THE FUR-TRADE.*

The human race differs from most of the other highly organised animals in being nearly destitute of any natural covering to the body. In the latter, the

* For the splendid specimens of furs exhibited on this occasion, the Society is chiefly indebted to Messrs. Poland, 21, Bow-lane; and for the stuffed specimens of fur-bearing animals, to the Zoological Society.

only use of the hair or feathers with which they are clothed is to afford protection against wet and cold. To man has been superadded the sense of modesty or shame consequent on complete exposure of the person. It is true a very partial covering will suffice to satisfy the wants of this moral feeling, when not strengthened by the physical necessity of protection against cold; but still the feeling itself exists so generally, that the reported want of it in one or two savage tribes, in the lowest state of wretchedness and degradation, can hardly be admitted as detracting from its universality.

In those countries the inhabitants of which made the most rapid advances in civilization, by domesticating the sheep the goat and the camel, and betaking themselves to agricultural labour in fixed habitations, the art of obtaining from the animals just mentioned an annual supply of hair or wool, without slaughtering them, would soon be discovered, and with it the method of spinning and weaving them into cloths of various texture, better accommodated to use than skins and more susceptible of ornament through the skill of the dyer and of the embroiderer. But all documents of these primitive ages, if such ever existed, have perished; and it would be idle to take up your time by substituting in their place theories, which, however plausible, might be destitute of any foundation.

There is however one remarkable fact in relation to the subject now before us in which all antiquity, as far as it speaks at all, concurs; namely, that the vallies of the Tigris and Euphrates and of the Nile as well as Syria from the sea-coast eastward to the

great desert that parts it from Mesopotamia were occupied by highly civilized nations, subject for the most part to absolute monarchs and clothed in fabrics of cotton linen and wool; while the grassy treeless plains extending from the Aral sea westward as far as the mouths of the Danube, along the northern border of the Caspian and Euxine seas and the intervening chain of the Caucasus, were occupied, or rather traversed, by independent tribes of horsemen shepherds clothed in skins and fur. Under the dreaded name of Scythians, they occasionally forced the passes of the mountains and ravaged in temporary inroads the plains of Mesopotamia and the vallies of Syria; or, crossing the Araxes between the Aral sea and the Caspian, produced a more permanent impression on the eastern frontiers of Media and Persia. Herodotus records a conquest of the open country of Mesopotamia by the Scythians; an incursion into Scythia, in revenge of this, by Cyrus in which that monarch lost his life; and an expedition, equally fruitless, across the Dardanelles, by Darius. But besides these mutually hostile incursions, we may conclude, with great probability, that more or less of commercial intercourse took place at the common frontier of the two countries, and that the manufactures of Babylonia were exchanged for the natural productions of the Scythian plains and of the interminable forests on their northern boundary. Horses cattle and the finer kinds of furs would, in all likelihood, form the chief commodities on the part of the Scythian traders. That the latter articles were known and esteemed by the nobles of

Babylon we have very satisfactory proof in the apocryphal book of Judith, and that they were applied to the same purposes that Persian carpets are at present in the same country. It appears from this book, that Nebuchadnezzar king of Nineveh, having conquered Arphaxad king of the Medes, sent his general Holofernes against the Jews. While he was besieging Bethulia, Judith came out to him and was lodged in an apartment of his tent, "and her maid went and laid *soft skins* on the ground, which she had received of Bagoas (chamberlain of Holofernes) for her daily use, that she might sit and eat upon them."—*Judith*, xii. 15.) This passage is the more valuable from the exceeding scarcity of notices in ancient authors respecting the use of furs as an article of state or luxury by the inhabitants of civilized countries. The Jews seem to have been precluded from the use of furs by the enactments of the Mosaic law respecting unclean animals (Levit. xi. 29); and the Greeks and Romans esteemed them badges of rusticity and barbarism. The Persians therefore, using this appellation in its largest sense, seem to have been the only civilized nation of antiquity to whom furs were an object of luxury. Ælian, who wrote about the year 110 of the Christian era, informs us in his book on animals (*περι ζωων*, xvii. 17.), that a certain species of mice are found in the district of Teredon in Babylonia, the soft skins of which are brought by traders to Persia, where they are sewn together into garments remarkable for their warmth. We have nothing to enable us to identify the species of animal here mentioned;

but it might very well have been some small creature of the weasel kind, for both Greek and Roman writers were accustomed to call all such by the general name of mouse. Zonaras writes, that Sapor king of Persia possessed a tent, made at Babylon in party-work of different colours, of the skins of animals natives of that country (*εκ Βαβυλωνος δερμασιν εγχωριοις ποικιλωτερον ειργασμενη*).

Having thus shown that Babylon had by this time become a mart for furs, where they were made up into pelisses and the linings of tents, I shall now, by the citation of a few authorities, endeavour to show you the feelings of the Romans with regard to the use of furs.

The poet Ovid, after having spent the flower of his age in the license and luxury of the metropolis of the empire, was banished by Augustus to the frontier fortress of Tomi on the south shore of the principal mouth of the Danube. Here he passed the last four or five years of his life, occupying and consoling his leisure in the composition of nine books of epistles in verse to his friends in Rome, in which are many striking descriptions of the wild country and rude climate and of the wilder and ruder tribes of Scythian marauders by whom it was vexed.* During the summer, the wide stream of the river defended the small fortress and its scanty garrison from annoyance; but early in the winter not only the river but the sea itself to a considerable distance is frozen. Bands of savage barbarians on horseback, or mounted on their creaking waggons drawn by oxen, are then seen cross-

* Tristia, iii. Eleg. 10 ; v. Eleg. 7 and 10.

ing the ice. As they approach, you distinguish their long loose trousers; the upper part of their bodies except the face buried in fur, their beards and disordered hair matted with ice: the whole open country becomes their prey; the farm-houses are set fire to, the cattle driven off, the people massacred, except the young and robust, who, with their hands tied behind them, are goaded to keep pace with the rapid motions of these mounted savages. As they retire, they surround the petty fortress and discharge into it, as much from contempt as enmity, a shower of poisoned arrows.* Associated with such objects of dread and disgust, no wonder that a hairy cloak appeared to the affrighted poet and his friends at Rome as the very opposite to luxury and civility.

Tacitus, in his interesting treatise on the manners of the Germans written in the reign of Trajan, having occasion to describe the Fenni, one of the most barbarous and distant tribes, characterizes them in terms of energetic contempt, very inadequately represented by the following translation.† "The Fenni lead the life almost of wild beasts, in a state of foul penury, without arms horses or homes: their food is the wild herb, their clothing skins, their resting-place the ground."

The poet Claudian flourished in the reign of Hono-

* A Scythian inroad is the subject of the engraving prefixed to this paper.

† Fennis mira feritas, fœda paupertas; non arma, non equi, non penates; victui herba, *vestitui pelles*, cubile humus.—*Germania*, 46.

rius, about the year 390. At this time considerable intercourse, of a hostile or friendly kind, took place between the Scythian or Sarmatic tribes north of the Danube and the subjects and government of the Constantinopolitan empire. We meet therefore with frequent mention of these tribes in the poems of this writer, which are chiefly panegyrics and satires composed on public occasions. In one of them* he describes a victory obtained over an army of Getæ that had penetrated into the passes of Greece. The furred youth, says he, are mowed down, their waggons swim in gore :

Plaustra cruore natant, metitur *pellita* juventus.

In another poem† he speaks of the furred assembly of the Getic chiefs, *pellita* Getarum curia ; and lastly, in his celebrated satire against Rufinus ‡ the prime minister of Honorius and the political enemy of his patron Stilicho, after mentioning the Getic body-guard of Rufinus, he discharges all his indignation on him for assuming the furred dress of these barbarians, revocat fulvas in pectore *pelles,* and even venturing to appear on the seat of justice wrapped in fur, mœrent captivæ *pellito* judice leges. These passages are interesting on several accounts. They show us, in the first place, that the manners and dress of the Scythian tribes had undergone no material change for many centuries ; in the second place, that the inhabitants of Constantinople had completely adopted the feelings of the Romans with respect to furs being the characteristic

* De IV. Cons. Honorii, 466. † De Bello Get. 481.

‡ In Rufinum, ii. 82.

outward and visible sign of barbarism: and thirdly, that a man of high rank, either as a compliment to his Scythian guard or from some motive of singularity or ostentation, had ventured to show himself to the public even on the seat of justice in robes of fur.

The passage I have already quoted from Tacitus shows that one of the most remote of the German tribes used the skins of animals as their ordinary clothing; and a still more striking passage, which I shall have occasion to cite by and by from the same author, shows that this custom was common to all those people. Sidonius says the same thing also of the Burgundians. Thus the whole northern and eastern frontier of the Roman empire was covered by nations of warlike barbarians clothed in furs, except where long intercourse with the Roman garrisons had introduced in some degree the use of cloth with other commencements of civilization.

In the 6th century, the defensive resistance of the divided and enervated Romans availed no longer; the barriers of the Danube the Rhine and the Rhætian Alps were forced by the nations of Germany and Sarmatia, in search of plunder or of permanent settlements. Italy, in the reign of Justinian, received for a time a Gothic king and the confederation of the Franks established themselves in Gaul. The intruders, while enjoying the luxury and conveniences of the countries which they had conquered, retained however some of their barbaric tastes, and among others their fondness for furs; though the milder climate to which they had transferred themselves no longer rendered this species

of clothing an article of absolute necessity. While therefore they cast aside the coarser skins and replaced them by the more convenient and agreeable fabrics of Italian and Gallic looms, they sought out the more eagerly for the rarer richer, and more costly furs, as well for the purpose of ostentatious luxury as of the warmth which they afforded. Jornandes, who was secretary to the Gothic kings of Italy and wrote his history of the Goths about the year 552, in speaking of the Suethans or Swedes, describes them as a race who live hardly, but are clothed most richly in furs of a becoming blackness. These are the people, adds he, who transmit, by commerce, through many intervening nations, the skins of sables for the use of the Romans.*

In the rapid sketch that has now been given, I have endeavoured to convey a clear idea of the country which in all ages has been inhabited by people characterised by wearing fur. This material of dress was necessarily imposed on them while occupying their native plains, by the severe cold of the climate; but when they had established themselves in the milder countries of southern Europe, the habit, at first superinduced by a natural want, was retained as ministering to luxury and the desire of personal distinction. At the same time, and indeed considerably previous, a similar taste had been excited,

* Gens Suethans—hi sunt qui in usus Romanorum sapphirinas pelles, commercio interveniente per alias innumeras gentes, transmittunt, famosi pellium decorâ nigritudine. Hi cùm inopes vivunt, ditissimè vestiuntur.—*De Reb. Get.* cap. iii.

through the medium of commerce, among the nobles of Persia, many of whom were probably of Scythian or Tartar extraction.

A demand for furs having thus been caused in the Roman empire, chiefly indeed in the western division of it, our next inquiry is into the sources from which this demand was supplied.

We know from Jornandes, already cited, that sable-skins were obtained from Scandinavia and the shores of the Baltic. We also know, from various Greek writers of the middle ages, that there existed a considerable trade in furs from the mountainous countries whence flow the Tigris and Euphrates, and which block up the space between the Euxine and Caspian seas. The consumption of Mesopotamia and Persia appears not to have been sufficient to absorb the supply; and large quantities of small furs, under the name of skins of Pontic or Babylonian mice, were obtained through the Greek commercial establishments in the Crimea or the merchants of Cappadocia. Of these furs the principal and the only one which can be identified is the ermine. Julius Pollux informs us that a particular kind of robe was called Armenian as being made of the skins of mice caught in that country; and the terms Pontic Babylonian and Armenian mice are used so indifferently by the writers of that age, as to induce some antiquaries, particularly M. Du Cange in his very interesting memoir on Coats of Arms printed in the *Mémoires de l'Académie des Inscriptions, &c.* to suppose that the ermine is the only animal meant by these various expressions. The more

ancient writers who mention this creature call it *Hermelin;* now, this is the Italian adjective *Armellino,* Armenian, scarcely at all changed: whence I think we may fairly conclude, not only that the ermine derives its name from Armenia but that by far the greater part of the supply required for the princes and nobles of western Europe in the middle ages, was imported from that country by the merchants of Italy. I may here remark, that sables and ermines were sometimes confounded together by the old writers; a mistake which could never occur with regard to the animals themselves, one being nearly black and the other snow white. It has probably arisen from this: The Tartar name of the ermine according to Marco Polo, (Purchas, iii. 86—160,) is *zibelline,* and that of the sable is *zamboline;* and these similar words may easily be confounded by ignorant or careless writers, or by the modern reader who recognises the ermine only by its common name. Thus, in one French metrical romance we find the expression,

Si ot vestu un hermin engolé;

meaning ermine dyed red.* In another French Poet of the same age, we have the words,

chappes fourrées
De sobelines engoulées,

in which likewise the author obviously means ermine, it being impossible to dye sable of a red colour.

* To the same effect St. Bernard says, in his forty-second epistle, "Horreant et rubricatas murium pelliculas, quas Gulas vocant, manibus circumdare sacratis."

The ermine is a small animal, and therefore the number of such skins employed to line the full robes and mantles of princes and nobles, when furs were in their highest fashion and esteem, may readily be conceived as well as the enormous expense attached to the indulgence of this taste. In the account of Stephen de la Fontaine, silversmith and master of the robes to Louis IX. of France in 1251, is the following entry: "For three pieces and a half of velvet in grain, to make a surcoat a dress-mantle and a hat lined with ermines for the king against the feast of the star. For the said surcoat a fur lining of 346 ermines, for the sleeves and wristbands 60, for the frock 336." In all, 742 ermines for a single dress.

The four noble furs of those ages were the sable, the ermine the vair and the gris. The three former of these represented the three fur colours admitted into their armorial bearings. Every one at all acquainted with heraldry knows that ermine is represented by a white ground with black somewhat lengthened spots. These were intended to designate the black-tipped tails of the animals, the skins being sewn together either with the tails on, or the tails were first cut off and afterwards sewn in rows upon the skins, sometimes alone sometimes with a little wad of black lambskin on each side of the tail. This arrangement is so obvious, I may say so natural, that it would not have been worth a remark in this place, except for its connexion with the science of heraldry.

The vair was a squirrel,* obtained probably at that time, as it is at present, from the southern provinces of Russia. It has a white belly and a blue or rather dove-coloured back, on which latter account its colour when blazoned was azure. When these skins, entire, or at least only reduced to square pieces (called in ancient heraldry *pannes*) were sewn together, the result was a varied surface of bluish gray and white in alternate somewhat bell-shaped figures; but as the white of the squirrel's belly is far inferior to that of the ermine, it was the custom, for the more sumptuous kind of garments, to use only the back of the squirrel and to form the alternate white figures of ermine. This custom of spotting mixing and diversifying furs is supposed by M. Du Cange and others to be of eastern origin; and the tent of Sapor, already mentioned, has been cited as the earliest instance of it and particularly for that special mode of intermixing the furs called vair. Tacitus however describes the same fashion of variegating furs to have been in use among the German tribes long before the existence of Sapor or his tent. His words are these:†—"They wear also the skins of wild beasts, more negligently on the Roman borders, but more exquisitely prepared by those

* Vair is at present the provincial name for a squirrel in Devonshire.—See Marshall's *Rural Econ. West of England*, vol. i. p. 326.

† Gerunt et ferarum pelles, proximi ripæ, negligenter; ulteriores, exquisitius, ut quibus nullus per commercia cultus. Eligunt feras, et detracta velamina spargunt maculis pellibusque belluarum quas exterior oceanus atque ignotum mare gignit.—*German.* xvii.

tribes who, on account of their distance, are ignorant of the refinements introduced by commerce. For this purpose they select the skins of particular animals, and vary them with spots or with the skins of marine monsters* that inhabit the unknown northern ocean."

Respecting the gris heraldic antiquaries seem much in doubt. Some suppose it to be only the blue or gray back of the same squirrel as has just been described by the name of vair. This however is not very probable, especially as the common French name of the North American gray squirrel is *petit gris,* little gris, although in size it is equal to the vair. Greese and Graies occur in two lists of furs inserted in M. Chancellour's travels in Russia and Moscovia 1544; and as Graye is the old English name of a Badger, the heraldic gris is probably the fur of this very animal.†

Charlemagne, who appears to have been a man of plain taste in dress, was accustomed to wear in winter a cloak of otter-skins ‡ according to Eguinard; but, according to Philip Mouskes who wrote a metrical life of Charlemagne, he wore a surcoat with sleeves furred with vair and fox.

"A tousjours en iveir si ot
A mances un nouviel surcot
Fourré de *vair* et de *goupis*
Pour garder son cors et son pis.

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* Probably seals.

† If not, it may be the Calaber or gray squirrel of Russia inserted in Dr. G. Fletcher's list of Russian furs as cited farther on in this paper.

‡ Fiber et lutra, utrumque aquaticum, utrique mollior plumâ pilus.—*Plin. Hist. Nat.* viii. 47.

Octher, a Norwegian chief, who gave an account to our Alfred about the year 890 of his discoveries towards the North Cape, informs us that the tribute paid by the Fynnes to the Biarmes or Swedes was skins of marterns reindeers and bears.—*Hakluyt.*

The martern martin, or lette as it is sometimes called, has continued in great esteem from the earliest to the present times. There are two species of it, the common and the pine martin, the fur of the latter of which is by far the best; and some of the darker varieties are not unfrequently mistaken for sable. It has been, indeed, supposed that the real sable was hardly known in the middle ages; and we are certain that some of the writers of this period use the word martin or martern as synonymous with sable.* Thus, Adam of Bremen, speaking of the passion for rich furs, says, "Ad marturinam vestem anhelamus quasi ad summam beatitudinem;" we are as anxious to obtain a garment of marterns as the joys of heaven. Where the word must evidently imply a fur of the finest quality.

The Anglo-Saxons had the same taste for furs as the other nations of Germanic origin; but the peltry trade of the Italian merchants seems not to have reached the remote island of Britain, whose inhabitants were confined to their native produce together with probably a few of the richer kinds brought by the Northmen and other semi-piratical traders from the Baltic: accordingly the list of Anglo-Saxon

* Si est le champ fait de brodure
De fine *marte sabeline.*—*Jacques Millet.*

furs includes little more than sables beavers foxes cats and lambs.

The era of the crusades appears to have been the time when the luxury of furs attained its height in western Europe; and sumptuary laws issued from time to time from the sovereigns of France and England and the princes of Italy, for the double purpose of restraining the general extravagance in this article of expense and of confining the use of the most esteemed furs to the higher ranks of society. In proof of this we may cite the sumptuary laws of Charlemagne and Philip the Fair, as well as three acts of the English parliament; one passed in the year 1158 in the reign of Henry II. prohibiting altogether, on the plea of preparation for an expedition to the Holy Land, the use of sable vair or gris; and two other acts in 1334 and 1363, prohibiting any one from the use of furs whose income was less than 100*l.* a-year. These attest at once the extent of the fashion and the vain attempt to control or regulate it by law. Not only the nobility clergy and gentry but the merchants and opulent burghers indulged in the fashionable luxury. The ermine was appropriated with considerable strictness to the order of nobility and knighthood; but the gris the martern the minever and squirrel, were also worn by magistrates and officers of corporations, by rich citizens and their wives. The warriors of the first crusade in 1097, led by Godfrey of Bouillon, passed through Constantinople in their way to the Holy Land, and displayed all their sumptuousness in an

interview with the then Emperor Alexius Comnenus. Albert, canon of Aix-la-Chapelle, in his account of this interview, describes the splendid vestments of purple, of cloth of gold, of ermine martern gris, and vair which they exhibited on this occasion, being such, says he, as are principally worn by the nobles of France.* Whence we may conclude, that the four furs above enumerated still bore the highest estimation, and that the sable was considered rather as a rich variety of the martern than a distinct species. The minever at this time begins to make its appearance in the list of furs: it is also called laset, and is the same animal which in later times has been known by the name of mink, a Russian animal of the weazel kind, smaller than the martern and amphibious like the otter. This fur continued long a very fashionable edging of robes worn by gentlemen, and in general by the richer of the middle classes of society.

Furs tournaments and heraldry, which have a close connexion with each other, lasted in high glory for about three centuries and then began to decline together. In proportion as fire-arms were introduced the use of armour ceased. It now became absurd for mailed knights, resplendent in their coats of arms, to show themselves in the front of battle a conspicuous mark for shot; and the stern compulsion of an

* In splendore et ornatu pretiosarum vestium, tam ex ostro quam aurifrigio et in niveo opere harmellino, et ex mardrino grisioque et vario, quibus Gallorum principes præcipuè utuntur.—*Albert, Ac.* JJ. 16.

improved system of military discipline replaced the men-at-arms and other retainers of the feudal chiefs by hired soldiers, tore down their patrimonial banners, and displayed instead the national flag. Improvements in domestic accommodation attached people more and more to their homes and to in-door social enjoyments. The use of silk* obtained an ascendency over that of fur, as being an article which admitted of being manufactured into an infinite variety of forms and fabrics, and thus better able to accommodate itself to the capricious vagaries of fashion than furs, which, though rich, are always heavy, literally as well as metaphorically; and the colours of which, though harmonious, are wholly incapable of rivalling the brilliant rainbow tints of the dyer.

England, except perhaps in extremely remote times, never produced furs sufficient for its own consumption.† Two commercial events, however, have at different times made London one of the centres of the fur-trade. The first of these was the discovery by Richard Chancellour, in 1553, of the passage by

* Silken velvet and plush were perhaps first invented as an imitation of fur in a richer material.

† Imports into Chester from Ireland in 1430:—

Hides and fish, salmon, hake, herringe,
Irish wooll, and linnen cloth, faldinge;
And *marterns good* be her marchandie
Hertes' hides, and other of venerie.
Skinnes of otter, *squirrel*, and *Irish hare*,
Of sheepe, lambe, and *foxe*, is her chaffare,
Felles of kiddes and *conies* great plentie.

Hakluyt, i. 199.

sea to the northern coast of European Russia, and especially that great gulf commonly called the White Sea, at the bottom of which Archangel was afterwards built. Russia was at that time a barbarous country, moderately populous, pressed on the one hand by the Poles and on the other by the Tartars, and bounded on the east by the Uralian mountains. Its sovereigns, at that time content with the title of Tsar or duke, reigned at Moscow. The arrival of Chancellour was considered as an important event. The duke invited him to his capital, patronised him, and allowed the company of merchants by whom he was sent out to establish two or three trading posts on the White Sea, to have a warehouse at Moscow, and to send out from thence trading parties to the shores of the Caspian and into Persia. Manufactures of silk and of woollen formed the chief exports, and among the imports were furs. Chancellour himself wrote a very interesting though brief account of the country; from which, and from the other official letters of the agents of the company, I have taken such passages as bear on the subject of our present evening's illustration. From the country stretching from the river Dwina which runs into the White Sea, northward and westward to the Uralian mountains, were procured sables marterns beavers, foxes white black and red, minks ermine miniver graies and wolverings;* the finest sables and black foxes being procured by tribute from the Samoeds, who live at the mouth

* Not the wolverine, quickhatch, or carcajou of Canada, but probably the glutton, *ursus gulo*.

of the Oby.* Siberia was not yet conquered by the Russians; but from several parts of that extensive country were obtained by barter a considerable number of valuable furs.

Dr. Giles Fletcher, embassador to the Tsar of Russia in 1588, also describes the fur-trade of Russia in the following words:—"Their chief furs are these, black fox, sables, luzernes, dun fox, martrones, gurnestalles or armins, lasets or minever, beaver, wolverin, the skin of a great water-rat that smelleth naturally like musk, calaber or gray squirrel, red squirrel, red and white fox. Besides the quantity spent in the country, there are transported out of the country, by the merchants of Bucharia Turkey Persia Georgia Armenia and some part of Christendom, to the value of 4 or 500,000 rubles (the ruble at that time being equal to about 2 oz. of silver). The best sable groweth in the country of Pechora Momgosorskoi and Obdorskoi, the worser sort in Siberia and Perm: the black fox and red come out of Siberia; white and dun fox, white wolf, wolverin, and white bear, from Pechora; the best martrons from Siberia Codam-Morum Perm and Cazan; lusernes minever and armin are best out of Galets and Ouglits: the beaver of best sort breedeth by Cola." Of these, the sable undoubtedly held the first rank; for Anthony Jenkinson, one of the agents of the company, having seen the Tsar's wardrobe, writes, that "the crown was lined with a fair black sable worth forty rubles, and

* The staple for these latter was the town of Calmogro.

his gowns and garments were of rich tissue and cloth of gold, and all furred with very black sables," no other fur being mentioned. Next in rank to the sable were reckoned the luserne and black fox: what the former of these animals was, I have not been able to find out; but it was evidently a valuable fur, as the presents from the Tsar to Queen Mary* and afterwards to Queen Elizabeth consisted entirely of sables and lusernes, with some large and beautiful skins not particularised. Foxes black white and russet, martrons minevers ermines and sables, formed the chief furs purchased by the company; and it appears that gray squirrels' and some other smaller furs were imported as private ventures by their servants. But the trade, though it flourished for a time, soon began to decline. A proclamation from the queen† prohibited in England the wearing of any except native furs, and although this, like former proclamations and acts of parliament with the same object, would in vain have opposed the omnipotence of fashion, the taste for furs seems nearly to have become extinct, the prices obtained by the company were in many cases less than

* Gifts sent in 1656 to Queen Mary by the Tsar of Russia:—
6 Timber (240) of sables, rich in colour and hair.
20 Entire sables.
30 Lusarnes.
6 Large and great skins very rich and rare.—*Hakluyt*, vol. i.

† Make not any great provision of any rich furs, except principal sables and lettes; for now there is a proclamation, that no furs shall be worn here but such as is grown here within the realm.—*Letter of the Moscovia Company to their Agents*, 1560.

they had given for the skins in Russia, and the trade was abandoned.

Some years afterwards, the discoveries in North America, of the river St. Lawrence by the French and of Hudson's Bay by the English navigator whose name it bears, opened to the two great maritime nations of Europe a new and almost immeasurable extent of country abounding in fur-bearing animals. The French were the first to avail themselves of this advantage. A powerful colony was settled in Lower Canada, and the possession of water carriage by the St. Lawrence and its tributary streams and sea-like lakes gave them ready access to some of the best fur-ground in that continent; of this they actively and adroitly availed themselves, conciliating the good-will and attachment of the savage tribes, by condescending, with less reluctance than any other European nation, to form domestic relations with them and to adopt their manners.

The quantity of furs obtained annually by the French during their possession of Canada, was very great; being derived not only from the St. Lawrence, but from the upper part of the Mississippi, on the banks of which river they had fixed forts and trading stations.

The Hudson's Bay Company, incorporated in 1670, was only a private association of a few adventurers, and therefore, independently of the disadvantages of its local situation, possessing neither the capital nor enterprise of the French colony. Its importation of furs, though very considerable, never equalled that of

the latter. The conquest of Canada in 1762 suspended for a few years the fur-trade of that province. It recommenced in 1766 chiefly under the management of Scotch traders; but again declined, partly from the rivalry of the Hudson's Bay Company. Obstructed in their endeavours to open a fur-trade with the tribes of native Indians in the country north of Canada, the commercial enterprise of that colony sought out a field for its exertions in the western wilderness. In 1775 a trader of the name of Jos. Frobisher penetrated to the neighbourhood of Lake Winipeg which, with other lakes and rivers, fills up the space between Lake Superior and Mackenzie's River. From this country vast quantities of very valuable furs were obtained, to which were also added a considerable number by intercepting in part the course of the Indian trade with Fort Churchill, one of the stations of the Hudson's Bay Company. A few years after however the small-pox broke out among the natives, and, sweeping away the greater part of the population and deterring the remainder from intercourse with Europeans, nearly put an end to the trade in this quarter. Another association was formed in Canada in 1783, calling themselves the North-west Company, which appears to have been a consolidation of the Scotch and other interests for the purpose of exploring the country which still remained between Lake Winipeg and the Rocky Mountains. Mackenzie was one of the agents employed on this occasion, and his enterprise and perseverance were rewarded by the discovery of the large river which bears

his name, and which, with a course in general parallel to that of the Copper-mine River, which had already been explored by Hearne a servant of the Hudson's Bay Company, empties itself, also like that river, into the Frozen Sea which forms the northern boundary of the American continent. Jealousies squabbles, and occasional scuffles between the agents of the two companies still took place to their mutual loss; at length an accommodation was brought about, and the furs obtained by the Canadian traders are now disposed of at the annual sales of the Hudson's Bay Company.

After the United States had achieved their independence, the fur-traders of that country spread themselves along the dubious N.W. line of frontier which separates the territory of the United States from that of the British nation; and the presidency of Jefferson was illustrated by the expedition of Lewis and Clark, who traced up the great Missouri to its principal sources in the Rocky Mountains, discovered on their western slope the feeders of another great river which they traced to its junction with the sea on the western coast, and to which they gave the name of the Columbia. By both these channels furs found their way to New York; and the most advantageous mode of disposing of a great part of them has been found to consign them to London, in which city is thus concentrated nearly the whole of the North American fur-trade.

While the fur-bearing animals were thus attracting the commercial enterprise of the French and British

from the eastern to the western shore of North America, the same motive and the same results were exciting and rewarding the perseverance of the Russians, and drawing them continually forwards from the Ural Mountains the western boundary of northern Asia, to the sea of Kamtschatka which washes its eastern shore. The conquest of Siberia and its annexation to the Russian empire took place in 1640, thirty years before the incorporation of the Hudson's Bay Company. The Kuril and Aleutian isles in the sea that divides Asia from North America were discovered and taken possession of in 1745, by which the fur of the sea-otter was first introduced into commerce, and which while rare obtained incredible prices in the Chinese market. In 1780 the fur-bearing animals had already become scarce in Siberia while the demand continued undiminished in the Asiatic markets: this led to new exertions; and when Cook, in the course of his exploratory circumnavigation, was engaged in surveying the western coast of America north of Nootka, he found that the Russians had already on some points opened an intercourse for furs with the inhabitants. The sea-otters obtained by the crews of his ships sold in Kamtschatka for the Chinese market at prices which astonished them, and which gave birth soon after to British and American expeditions to the same quarter and even excited some signs of spirit in the sluggishness of the Spaniards of Monterey and California. The Russians however being nearest and in force, and stimulated by commercial jealousy and national

ambition, established a colony on the American coast and now possess the north-western extremity of that continent. Thus the fur-traders of different nations, the one setting out from the western boundary of Asià, and the others from the eastern boundary of America, have traversed these two great continents and now find themselves face to face on the western shores of America. No new fur-ground remains to be explored; and although the supplies of this commodity may not, for some years, diminish in any very sensible degree, yet it is evident that the summit of the trade has been reached and perhaps overpassed.

In Prof. Pallas's Travels in Russia occur the following notices respecting the *habitats* of some of the fur-bearing animals of that country in the latter half of the last century.

In 1771 sable of very fine quality was still abundant in the Altai mountains, also martens, which are not found in Siberia and are rare in the upper Jenissei. The glutton abounds in the upper Jenissei. The Altai mountains also furnish fine foxes lynxes gluttons otters and beavers.

In the government of Krasnoiarsk and near that place are still many sables but not of the first quality; better ones are found beyond the Jenissei, but those of Oudinsk are better. Beavers and otters abound beyond the Jenissei, the latter often sell for seven roubles a piece, as also do the lynxes without their fore feet, which being striped are sold separately. Gluttons if quite black bring four roubles. Ermines

abound and while there was a demand for them in China brought 25 copecks.

About Samara on the N. Volga occurs the musk-rat, ermines, and sables with a bright fine colour under the throat.

The Russians exchange with the Bucharians skins of beaver and otter, and receive black and gray lamb skins tiger and tiger-cat skins.

The fur-trade of England is both an importing and exporting one. The imports for our own consumption are blue and white fox from Norway and Iceland, martern and fitch from Germany and France, bears silver and gray, sables ermines squirrels hares and lambskins,* from Russia; seals† from the southern ocean, and chinchilla from South America.

The imports, partly for home consumption and partly for re-exportation, are the furs of North America. Several of the smaller animals which were imported from Canada while that colony was in pos-

* Of which there are the four following varieties:—black wavy, from Astracan; black curly, from the Ukrain; gray curly, from the Crimea; gray knotty, from Persia. According to Burnes (Travels in Bokkara) the jet black curly faced sheep, the skins of which are used in Persia for caps, are peculiar to Karakool a small district between Bokkara and the Oxus. The skins of the male lambs are most esteemed: they are killed when five or six days old. A few skins are from unborn lambs; these are not curled but are as fine as velvet: 200,000 skins of lambs are annually exported.

† Seals from the Arctic countries have only long hair; those from New Shetland and other southern polar countries have (with few exceptions) soft down beneath the hair.

session of the French, and which formed the *menu pelléterie* of the traders, are found to be no longer worth the trouble and expense of collecting: these were chiefly ermine and squirrel, but considerably inferior in quality to similar skins from Russia. The American furs which are at present brought to London are:*

Bears of several species and colours.

The black are used for hammer-cloths, for grenadiers' caps and other military equipments. (In the United States for coverings of sleighs.)

The russet, cinnamon, or Isabella bear, for muffs.

The silver or gray. The hairs are *tipped* with white, whereas in the black bear entirely white hairs are intermixed with the others.

The white or Polar bear, for rugs.

Raccoon.

A coarse fur, few of which are brought, and are re-exported to Germany and Poland. The fur is also used by the hatters.

Badger.

A soft very fine fur of a mottled or hoary gray colour. The fur of the European badger is darker and coarser. Exported to the continent.

Wolverine, or quicquehatch. Gulo luscus.

The fur of a black colour and resembling, but inferior to, that of the bear. Also exported to the continent.

Vison, or mink, lesser Otter, Jackash.

Amphibious; very similar to the Russian mink, but the fur of inferior quality. It is used here, but more on the continent, for trimmings and muffs.

* This list is chiefly taken from Richardson's Fauna boreali-Americana.

Martin, or martern, or pine martin.

A fur of very general use, here for muffs and trimmings, abroad for the same purposes and for almost all the uses to which the better kinds of furs are applied. The darkest coloured,* from the rocky and woody districts of the Nipigon, are the best and go popularly by the name of sable; but the true sable is not a native of America. The wholesale price of skins of the first quality is about twenty shillings a-piece.

Peckan, or fisher.

Fur yellowish; in quality inferior to the mink and pine martin but twice the size of this latter, and exported to the continent.

Otter.

Larger than the European species; a warm, rich and useful skin, consisting of a fine, waved and shining down, about as fine as beaver-wool but shorter, mixed with long coarse hair. Chiefly exported.

Sea-otter.

An exceedingly close, fine fur, jet black in winter, when it is in perfection, exceedingly soft with a silken gloss interspersed with shining silvery hairs, used a little in England but chiefly sent to Russia and China. Fine skins even now fetch, at first hand, from 10*l*. to 15*l*. The fur of the young animal is a beautiful brown, like fine velvet, and covered with coarse white hair.

Wolf.

Of this there are several species and varieties, larger than the European, and distinguished in the trade by their colours gray white and black. They are chiefly exported.

* The paler varieties are sometimes dyed black.

Fox.

Of this also there are many kinds. The white, or Arctic fox, is now coming a little into use here for muffs and tippets ; it is a fine fur and has nothing of the rank smell of other species of fox.

The silver or black, and the cross-fox,* are chiefly sent to Russia. The decided taste in Russia is for dark-coloured furs : hence those which are at the same time black and fine are the most costly. The black fox of America, though a far more valuable fur than that of any other American fox, is not comparable to the Russian, the skins of which are popularly said to be worth their weight in gold, and have actually been sold for 300 or 400 roubles a-piece.

The red fox, a much larger and fuller fur than the European fox, and of a bright rust-colour. It is used here for muffs and trimmings, and a considerable demand exists for them in Greece.

Lynx—wild cat of the traders. Loup-cervier.

This is a long hoary fur, of no great beauty in its natural state, but when dyed meets with a ready sale under the name of *lustered lynx*.

Beaver and musk-rat.

In this country used only by the hatters, but worn abroad as a fur.

Hare and rabbit.

Used chiefly by the hatters, and for common trimmings, &c.

* The cross-fox has a thick long fur, mottled black and white dashed with rust-colour, with certain cruciform markings on the shoulders.

One fur, and one only, is peculiar to England, namely the silver-tipped rabbit of Lincolnshire. This fur is a dark or lighter gray, mixed with longer hairs tipped with white. It is little used in this country but is readily purchased abroad, especially in Russia and China. In assorting it for these markets, it is however necessary to be careful with respect to the colour, for while the Russian will eagerly purchase the dark-coloured skins he makes no account of the gray ones. The Chinese are equally fastidious, but their taste happens to be the reverse of the Russians. Thus the fur-merchant, to dispose of his commodities to the best advantage, must be familiar with the caprices of fashion on the other side of the globe; I say the caprices, because a few years ago none but dark skins were saleable in China.

The great sales of furs by the Hudson's Bay Company and other parties take place in the month of March, and are attended by many foreign merchants who select what suit their purposes and consign them to Leipsig: here they are disposed of during the great fair in that city and are hence distributed to all parts of the continent. The chief demand and consumption of furs is now among the nations of Slavonian and Tartar extraction, either inhabiting their native seats or retaining their original love of furred clothing though settled in countries where the physical necessity for their use no longer exists. Such are the Poles the Russians the Chinese the Persians the Turks even under the burning sun of Syria and Egypt, the Bucharians and the various tribes of independent

Tartars. Among the nations of Gothic origin occupying the middle and western parts of Europe, furs are chiefly used in common dress by women and soldiers, and officially by magistrates, from the ermine robe of the sovereign to the gown of the common councilman trimmed with fitch or martern.

The American furs come in their raw state, that is, merely dried; they are dressed here by treading them with refuse butter, which makes the skin supple and not liable to break or tear: but as this cannot be done without also greasing the hairs, it is necessary, after treading, to turn them for some time in a revolving barrel set on the inside with spikes, and containing chalk gypsum or saw-dust, which absorbs the superfluous grease.

V. ON FELTING AND HAT-MAKING.

The use of hats, that is of caps with brims to them, is of very ancient date. Among the Greeks, the Dorian tribes, probably as early as the age of Homer, were characterised by the broad brimmed hats which they wore when on a journey. The same custom prevailed among the Athenians, as is evident from some of the equestrian figures in the Elgin marbles. The Romans appear in general to have used no covering for the head except a corner of the toga or upper garment; but at sacrifices and festivals they wore a bonnet or cap, and, this being permitted only to free men, part of the ceremony of manumitting a slave consisted in putting one of these caps on his head. But on a journey, the Romans were accustomed to wear a hat called *petasus* with a margin wide enough to shade their faces from the sun.

In the middle ages the bonnet, or cap with a narrow margin in front, appears to have been in use among the laity while ecclesiastics wore hoods or cowls: but Pope Innocent IV. in the thirteenth century allowed to the cardinals the use of scarlet hats. About the year 1440 the use of hats by persons on a

journey appears to have been introduced in France, and soon became common in that country, whence probably it spread to the other European states.

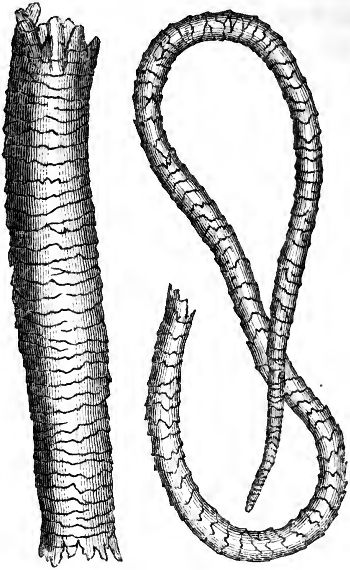
The cap of the ancients was certainly made of wool, and this as well as the hat was probably knit: I do not know when felt was introduced as a material for hats, but it is stated that the hat worn by Charles VII. of France on occasion of his triumphant entry into Rouen in 1440 was of felt.

Concerning the origin of felt little is recorded, and that little is perhaps not greatly to be depended on. A person, some call him a monk, having used some carded wool by way of socks, found that the fibres by long friction between the foot and the shoe had matted together so as to produce a firm texture like cloth, and from this hint arose the manufacture. Specious as this account or tradition may appear to be, it deserves to be remembered that the Turcomans from time immemorial have inhabited tents covered with black or white felt, and that some of the wanderers among the crusaders may have brought the art of felting from Asia to Europe. In order to understand the mechanism of felting and to qualify us to judge of the efficacy of the processes by which it is brought about, it will be necessary to enter into some preliminary inquiries respecting the structure of hair and wool; and for these I am chiefly indebted to a short paper by M. Monge published in the Annales de Chimie for 1790.

If we take a common hair of the head and, holding it fast by the root end, draw it gently between the

finger and thumb it passes through smoothly and with hardly any sensible resistance or interruption; whereas if we reverse the motion, holding the hair by the point and drawing it from point to root, a very sensible tremulous resistance will be experienced accompanied by a creaking kind of sound. Again, if we place a hair, loose, lengthways between the finger and thumb, and then by alternately bending and extending them give them a backward and forward movement, the hair will be put in motion; and this motion will be always from root to point whether the root be in one or the opposite position with respect to the two rubbing surfaces. A fibre of wool likewise in similar circumstances always moves in one direction. Every school boy knows that an ear of barley if put within his sleeve at the wrist soon travels upward to his armpit, and that a single awn of barley when rubbed in the direction of its length between the finger and thumb will move only one way, that is from root to point. The awn of barley is visibly jagged at the edges like a saw, the teeth pointing obliquely upwards, and this particular conformation is manifestly the reason why it is capable of motion in one direction but not in the contrary. A similar structure might be expected in hair and wool; and although this is but imperfectly shown by common microscopes, yet the greatly improved instruments of the present day render this structure quite obvious, as is evident from the accompanying figures, for which I am indebted to the graphic skill and accuracy of Mr. C. Varley.

The two figures represent two varieties of lambs' wool from Saxony: they occur intermixed in the same fleece. The larger are about $\frac{1}{400}$ of an inch in diameter, they are stiffer than the others and the markings on the surface are not so distinct: the diameter of the thinner fibres varies from $\frac{1}{1000}$ to $\frac{1}{5000}$ of an inch.



Wool in the yolk, that is, with the natural grease of the sheep adhering to it, will not felt; because in this state the asperities of the fibre are filled and smoothed over, just in the same manner as oil diminishes and almost destroys the action of the finest

files. But fine wool that has been properly scoured has so strong a tendency to mat or intertwist or felt, for all these words only imply various degrees of the same thing, that it cannot be spun into an even thread without being previously oiled sufficiently to suspend this tendency. Another example of the facility with which wool felts is the common flock mattress, which is made of carded wool sewn up in ticking: the warmth and slight motion which it gets by being slept upon are sufficient to cause the fibres to accumulate round certain points, whence result those knobs and lumps of imperfect felt which render it necessary after a time to empty the bag and recard its contents.

A piece of woollen cloth that has undergone no process after that of weaving, may without difficulty be unravelled; but after it has passed through the fulling mill it is no longer subject to this action, the filaments of which each adjacent thread is composed being entangled together by a species of felting. The result of this is that the cloth shrinks in length and breadth, but becomes proportionally thicker and more dense. The higher the heat is to which the cloth is exposed, and the longer it is continued, the more compact does the felting become; on which account it is that the modern practice of giving a gloss to woollen cloths by rolling them up very tight and then boiling or steaming them for some hours, gives them a compactness and leathery consistence in which all the advantages both of felt and of woven cloth appear to be united.

But the mere structure of wool and of hair, as I have now described it, is not of itself sufficient to account for the formation of felt: on the contrary it might be expected that the filaments being, when put in motion, free to move only in one direction, should continually diverge more and more from one another. This would actually happen in an attempt to make dense felt of unprepared hair of any kind, because all hairs are straight, or rather have only one gentle curve from point to root, and likewise possess a considerable degree of stiffness or elasticity. The fibre of wool on the contrary is naturally crinkled or of a zig-zag figure which it retains with great pertinacity, for if drawn out till straight it immediately contracts again to its former figure on being let go. Now this figure, besides opposing a great resistance to the progressive motion of the filament, must have a continual tendency to change the direction of such motion. The result of this would be the formation of a ball if the pressure were equal on all sides, or a plate or layer if the chief pressure were only in two opposite directions.

I now proceed to describe the art of hat-making; in which it is my intention to enter so far into detail as may be sufficient to set before you a clear and I should hope not uninteresting view of the several stages of a very important manufacture.

Hats are worn in this country by people in every rank of society, and till within the last thirty or forty years the only essential difference between them was in quality and consequently in price: the most costly

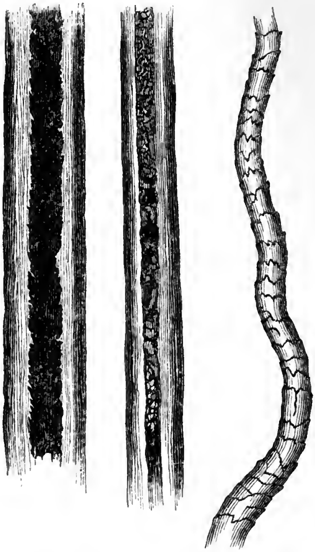
being made of the finest materials and by the best workmen, while the cheaper ones were of inferior materials and by inferior workmen. Of late however, the increased price of beaver has led to the substitution of silk for the roughing or nap of felt hats; and a diminution of weight has still more recently been obtained by the substitution of silk or hemp as the material of the body of the hat. We may therefore distinguish five kinds of hat. The beaver hat of which the body is felt and the nap of beaver; the plate hat, with a body of felt and a nap generally of musk-rat, neuter, or some other inferior fur; the felt hat, with a body of felt and without any nap; the silk hat, with a body of felt and a nap of silk plush; and lastly a hat with a body of hemp or waste silk and a nap of silk plush.

The general mode of making the three first kinds being the same, I shall give as full a description as our present object requires of making the finest or beaver hats; after which a few words will suffice to describe the circumstances of difference between these and the other two kinds.

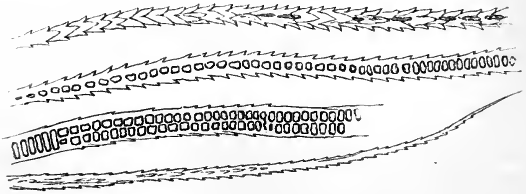
The materials of which the body of the hat is formed are the following. Lambs' wool (a magnified figure of which has already been given p. 158); Vigonia wool or red wool (*i. e.* the woolly hair of a species of camel a native of the Andes, the different varieties of which are known by the names of llama vicūna and pacos).

Of the three figures of red wool the two larger show the form of the hairs, about $\frac{1}{300}$ of an inch thick,

which are intermixed with the true down or wool which alone, from the markings on its surface, seems capable of felting.



The other material which enters into the composition of hat-bodies of best quality is rabbits' fur, of which the annexed figures are representations, the upper and lower showing the outer surface, and the

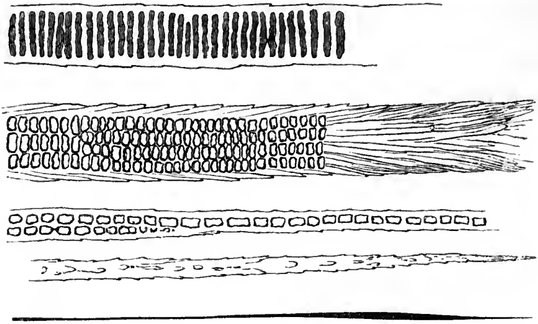


two intermediate ones the interior structure, the diameter of that with two rows of cells being about $\frac{1}{700}$ of an inch.

Rabbits' fur, although very tender pliable and possessed of but little elasticity, will not felt near so readily as wool, and as this is the only fur admitted into the body of the hat, which ought to be made as dense and compact as possible, a part of the rabbits' fur is subjected to the action of moderately dilute nitric acid or of acid nitrate of mercury. This is done by dipping a brush in the liquor and drawing it lightly in one direction over parts of the fur while yet on the skin. The acid thus acts chiefly on one side of the filaments, and by weakening them on that side disposes them the more readily to bend and double and change their direction during the operation of felting. The fur thus treated has its colour changed to orange red, on which account it is known in the trade by the appellation *carroted* fur. That which is imported from Holland is esteemed the best. The only kind of wool admitted into the finest hats is lambs' wool from Spain or Saxony. It is very carefully washed scoured dried and carded before it comes into the possession of the hat-maker.

The nap or, to use the technical word, the roughing consists chiefly of beaver down, the diameter of the filaments of which varies from $\frac{1}{1600}$ to $\frac{1}{2500}$ of an inch. Its structure is shown in the annexed figure.

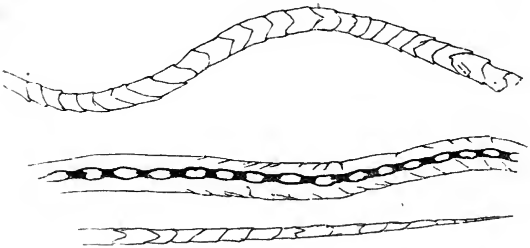
The fine down from the back of the common hare is also another article, but it must previously be separated from the long and coarse hairs with which it is naturally mingled. The diameter of these hairs is about $\frac{1}{300}$ of an inch and their figure is remarkable as they are very sensibly thicker towards the point than near the root. Of the five figures subjoined the lowest represents the free end of a hair, the one next above shows the external and the three others the internal structure. Of these latter the uppermost shows a portion of a hair as a dry transparent object, and the others as it appears in oil of turpentine.



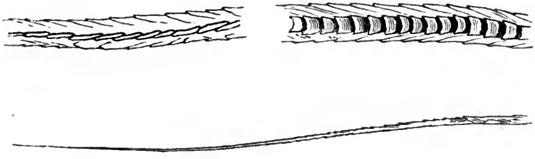
The down is about $\frac{1}{3000}$ of an inch in diameter and the outer and interior structure of it are represented in the two following figures.

The better qualities of down from the neuter and musquash are also employed, magnified figures of which are given below.

Neuter, $\frac{1}{2500}$ of an inch in diameter showing the outer and inner structure.



Musquash, about $\frac{1}{1800}$ of an inch in diameter.



The wools are shorn from the live animal, but the fur or down is taken from skins, first drawing out by means of a blunt knife the long and coarse hairs which are rejected, and afterwards shaving off with a very sharp knife the down for use. It is by no means a matter of indifference whether the down is drawn out of the skins or shaved off, since in the former case the down would have the bulbs or roots

attached to it and therefore would find great difficulty in making its way among the other materials.

The first process in the manufacture is weighing out the requisite quantity of materials for each hat: more than half consists of rabbits' fur plain and carroted, about one fourth is wool and the remainder is made up according to circumstances of red wool and sometimes a little carded silk. But often the only materials are rabbits' fur and lambs' wool.

The bowing-room has windows only on one side, beneath which is extended a table or counter divided by partitions into spaces about five feet long, one for each workman. The rabbits' fur being thrown in a heap near the left hand partition the workman takes a bow, somewhat of the shape of a fiddle bow but with only one string and much thicker in proportion in the framework: its length is above six feet, and in order to render it more easily manageable it is suspended by a strong cord. This bow being brought over the heap of hair the workman gives a strong vibration to the string by striking it with his thumb, the effect of which is to put in motion and completely separate from each other all the hairs that it touches; this is continued till all the lumps and clots are broken down so as to leave the hairs separate and lying as lightly over one another as possible. A light wicker frame like a common fire-guard is then employed to sweep the hair a little on one side in order to make way for the wool. This is bowed in the same manner as the hair, but with a larger bow having a stronger string. The hair and wool are then laid one

on the other by means of the wicker frame, and are again bowed till a complete and equal mixture of the two materials has been brought about and an even distribution of them has been made over the space that they occupy. The heap is now brought to a flat surface by light pressure with the back of the wicker frame and is then covered with an oil-cloth called a hardening skin. Pressure, at first very gentle and increasing by degrees, is made on the oil-cloth by the hand of the workman, till in a short time the fibres have intermixed forming a layer which however it requires care and practice to handle without tearing.

The hardening skin being removed, a piece of damp brown paper of the shape of an equilateral triangle is put on the layer, the edges of which are folded over so as to cover and inclose the paper except on one side; in this state it is folded up in a damp cloth and worked by hand, pressing and bending it, rolling it up and unrolling it, so as to give every fibre an opportunity of intertwining more or less with those in its neighbourhood and thus to form a thin though still imperfect and loose felt. The use of the moist paper is now evident, for without it the conical cavity which is afterwards to form the inside and brim of the hat would be obliterated by the mutual felting of the two interior surfaces. The manipulation which I have described is called basoning and the triangular body which is the result of it should be twice as large as it is intended to be reduced to by the next process.

This process is called planking. The apparatus consists of an iron boiler surrounded by seven or eight

inclined planes of plank each wide enough for a man to work at. The boiler is charged with a mixture of beer-grounds water and a little sulphuric acid, which is kept, as near as may be, just on the point of boiling: the workmen have their fingers unprotected but the palms of the hands are covered with sole leather. The beer-grounds employed by our hat-makers are only a substitute for the lees of wine used in France and other European countries, and each appears to be efficacious only from the small quantity of acid that it contains. In some of the French manufactories the use of lees of wine is abandoned and its place is supplied by an equivalent quantity of sulphuric acid, by which the following advantages are said to be obtained; the body is brought to its greatest degree of contraction in a somewhat shorter time, a heat less than boiling is quite sufficient, and the felt comes out of this process much cleaner, being free from the mud which it imbibes from the wine lees and which when dry becomes a fine dust which it is often necessary to beat out again. Our own manufactures might possibly derive the same advantages from discarding the use of beer-grounds.

The planking begins by the workman laying the felt body on the plank and sprinkling it with some of the hot liquor: he then rolls it up and unrolls it, pressing on it with the leather that is tied to the palm of his hand; during the whole of this operation it shrinks and becomes proportionally thicker and more compact. It is next dipped for a few seconds into the boiling liquor and is then rolled and worked on the

plank as before, the result of which is a still farther contraction and thickening of its substance. Lastly, the scalding is repeated, and the felt is worked and squeezed by means of a rolling pin called a walk-pin till it ceases to contract any farther. Thus the act of felting which was begun in the basoning is finished in the planking; and consists of rolling and pressing the layer of fibres first very gently and at the common temperature, then with a greater force assisted by the action of warm acid liquor and finally with the greatest force that the workman can apply and at a scalding temperature. The use of the acid is probably to facilitate the solution or removal of any oil or mucus which may be squeezed out from the hairs during the working, and which if allowed to remain among them would impede their tendency to felt. The body is then stoved till it is perfectly dry.

The next process is to put in the stiffening; which is a composition consisting for the most part of a saturated solution of shell lac in spirit of wine. This is applied by means of a brush to the inner surface of the body, and sometimes to the outer likewise: after which it is again stoved. By this means the felt is impregnated with a resinous substance capable of giving the required stiffness to it and also rendering it in a considerable degree impenetrable by rain or cold water. In the act of drying some of the lac is generally brought to the surface making it rough: this is removed by just dipping the body in a hot solution of alkali or of borax, which loosens the crust and allows it to be got off by the use of a copper

scraper called a draw board. It is then a third time stoved, and when nearly dry is singed by holding it over a blaze of shavings in order to remove the hairs which stand out from the surface of the felt.

The next process is putting on the nap or roughing. For this purpose the materials, consisting of $\frac{1}{2}$ or $\frac{3}{4}$ oz. of beaver fur, and some fine cotton, mixed occasionally with some of the other furs that I have already mentioned, are bowed down; and then, by the hardening skin, are made into a very tender imperfect felt of the shape of the body intended to receive it, but about three inches longer. A strip of this width being then torn off from the bottom of it, the remainder is just sufficient to cover the body while the strip is reserved for the under part of the brim of the hat. The roughing being thus prepared the body is softened by dipping it in the boiler and is then covered with the roughing, the strip being applied on the lower part of the inside. It is then taken to the plank, and the roughing is fixed to the body by first patting it down with a wet brush then rolling it in a hair cloth dipping it in the hot liquor and working it about as already described in the felting process, till the whole of the cotton* separates.

This is an operation that requires a good deal of care and experience as will be evident by considering what happens in the course of it to the hairs that

* Cotton is incapable of felting and is mixed with the roughing only for the purpose of enabling the smallest possible quantity of this latter very expensive article to be extended sufficiently to cover the surface of the hat.

compose the roughing. When first laid on they form a horizontal layer the individual hairs lying in all directions. As soon as the rolling and pressing begin, each hair is put in motion from root to point and enters the substance of the felt body. These hairs have considerable stiffness and elasticity and are moreover not weakened by the application of nitric acid: they therefore proceed in a pretty straight course into the felt, with the substance of which they form no union, and by a sufficiently long continuance of rolling and pressing would actually pass through the felt and be found on the inside instead of the outside. The process has been continued long enough when the hairs have penetrated by their root end sufficiently far to secure them from being drawn out in brushing the hat.

Up to this point the body has merely the shape of a cone without any resemblance to that of a hat; but the next process which is blocking begins to bring it into form. This is done by pressing-in the cone so as to form it into three or four concentric ridges and furrows; then the point is pressed outwards by introducing the finger, and, as it gets wider, the hand is used, by means of which, at length, the cone is brought nearly to a cylindrical shape; it is then drawn over a wooden cylindrical block and tied on, and in this state is ready to be dyed.

The ingredients of the dyer's copper are water, sulphate of iron, verdegris, gall nuts, and logwood; and in this mixture the hats are boiled for some hours, at the end of which time they are found to have ac-

quired an intense and beautiful black. They are first drained and dried and then are taken off the blocks and transferred to the finishing room. Here the hat is first placed over a jet of steam to soften it, then the brim is formed by turning up the lower margin, next the crown is strengthened by sticking a piece of scale-board on its under side and securing it by a piece of linen pasted over it; a block is afterwards put into it and the surface is smoothed and an uniform direction is given to the nap by means of warm and damp hair brushes and a plush brush called a *velours;* a hot iron is also employed for the same purpose.

It is next trimmed, that is, the binding, leather and lining are sewed in, and lastly it is finished off by being warmed and set up to the fashionable shape.

Having thus carried you step by step through the whole process of manufacturing a Beaver hat a few words will suffice for the Plate and Felt hat.

The body of the plate hat is entirely of lambs' wool, either Saxon Spanish Kentish or South down; and after basoning, previous to being planked is generally boiled in water and stale urine.

The nap or roughing is composed of various furs from that of the musk-rat which is only inferior to beaver down to those of the lowest quality, according to the price at which they are intended to be sold.

The felt hat is made entirely of wool without any roughing, the nap being merely scratched up by a card; and the stiffening is glue instead of lac.

Silk hats, as they are commonly called, were invented some years ago. They are hats with a thin

wool* body and a nap of silk. But as silk is not capable of felting, it was necessary to discover some other method of fixing it on the body. After many trials that which has finally been adopted, has been to take a piece of silk plush, made for this purpose with a pile of unequal length, and to sew it into the form of a cover just capable of fitting the felt body. This latter is then smeared over with an adhesive resinous mixture, and as soon as it has become dry the bag or cover of silk plush is drawn over it and fixed firmly to the body by means of a hot iron: it is then finished in the usual way.

The last variety of hat that I shall mention is one for the manufacture of which a patent has recently been taken out by Mr. Williams one of our members to whom I am much indebted for a full inspection of his process.

The body is made of hemp-tow or of waste silk finely carded or rather torn into distinct filaments; but as neither of these substances possesses in the slightest degree the property of felting, the following very ingenious and simple method has been hit upon of forming these filaments into hat-bodies very even, light and of greater strength than felt of the same thickness.

A fan with vertical pliers is fixed in a case or box open at top and united below with a horizontal trunk, in which are apertures that may be opened or shut at pleasure. It is evident therefore that if the fan is put in motion its effect will be to exhaust, to a cer-

* Sometimes the body of silk hats is straw plat.

tain degree, the air in the trunk, the consequence of which will be that a current of the outer air will set in through each of the apertures. A hollow frame of the shape of a hat, made of sheet zinc perforated with many small holes, is fixed in one of these apertures; and by simple mechanism a slow motion round its axis is given to it. A carding machine is so placed as to deliver the filaments of silk or hemp into the air above and a little on one side of the revolving frame. The filaments in their descent soon get into the current of air that is setting into the trunk through the perforations of the zinc frame, and are deposited quite evenly on its surface, and so rapidly that in about five minutes a layer of sufficient thickness for a hat-body is formed. A frame of perforated sheet copper of the same size and shape as the zinc frame is then put on, so that the layer of silk is inclosed between the two; and, though possessing in itself no coherence, is thus prevented from being in the least degree deranged. The frames being locked together are dipped into a boiler full of a stiffening mixture the chief ingredient of which is shell lac, they are then taken out and, when sufficiently drained, the upper frame first and afterwards the under one is removed, leaving the filaments of silk cemented into a hard light strong hat-body which is afterwards covered with silk plush in the manner before described.

I have now finished what I proposed to say on the subject of hat-making, but before I conclude allow me to direct your attention to a few other uses to which felt is applied.

The polishing wheels of comb-makers, workers in brass and other artizans are covered with felt, which by its spongy texture retains the putty and other polishing powders better than any other substance would do. The felt for this purpose is made into sheets of various thickness which are afterwards cut up into strips of the required size.

Gilders' baskets, in which they shake buttons and other articles of copper with an amalgam of gold (being part of the common process for gilding such substances), are made of felt. An old hat was first employed for this purpose, but it has been found more convenient to have larger baskets made expressly for such use.

Some kinds of large filters, as jelly bags, are now often made of felt, and a kind of paper made chiefly of wool is imported from Germany for the use of chemists and apothecaries; it is an excellent filter for hot liquors; acting rapidly and is not nearly so liable as a paper filter is to break through with the weight of the liquor.

Felt, chiefly in the form of old hat, is likewise extensively used by the engravers of blocks for calico printers, being inserted in those parts of the pattern where a large body of colour, or rather of mordant, is to be laid.

Old hat is likewise converted into an excellent polisher by dipping it into a weak solution of common alkali and then drying it. The alkali decomposes the black dye, bringing the iron, which is the base of it, to the state of oxide or rust which remains

disseminated as a polishing powder through the whole substance of the felt.

Lastly, felt is largely and increasingly employed in sheathing ships. A great quantity of cows' hair enters into the composition of this substance and, as it felts only very imperfectly, the sheets while making are passed through a boiler of pitch and tar which increases their cohesion. Sheathing felt is applied in uncoppered ships between the planking and sheathing, and in coppered ships immediately below the copper. Two most important benefits attend the use of this sheathing. In the first place it is a complete protection against the worm, which probably is incapable of working its way against the stiff bristles which are largely introduced into the composition of this felt. In the second place it is nearly impermeable to water, and being at the same time very extensible is not easily broken by the working and straining which takes place among the timbers of a crazy ship; hence many leaks are prevented which might otherwise damage the cargo or even hazard the safety of the vessel itself as well as the lives of the crew.

The foundation piles of jetties and of other buildings projecting into the sea have also, when covered by this felt, been secured from the attacks of those marine vermes which on many parts of our coast abound to such a degree as in a few years to destroy the strongest timbers.

A coarse felt like that last mentioned (but not tarred) has lately (1840) been employed with great

success as clothing for the boilers and working cylinders of steam engines; it being found to retard and in great measure to prevent the escape of heat from these parts into the open air. Hence has resulted a great saving in the quantity of fuel consumed by sea-going steam ships, it not being possible to apply to the heated parts of maritime steam engines the cover or *jacket* as it is called which is applied to the same parts of stationary land engines.

VI. ON BONE.

Most animal bodies are composed of soft and hard parts; of the latter, some are hard only when of a certain thickness but when thin are tough and more or less flexible and elastic; such as the horns of all mammalia (except of the stag tribe), the claws of the lion and tiger, the talons of the eagle, the horn of the rhinoceros, the coriaceous covering of tortoises and crocodiles, and the scales of fishes.

All these, by exposure to a gradually increasing heat, soften, enter into pasty fusion, give out the odour of burnt feathers, burn with jets of flame, and are consumed leaving behind a very small proportion of earthy matter. 500 grains of horn leave not more than from 0·25 to 2 of phosphate of lime. Boiling-water after long action takes up from most of them scarcely any quantity of soluble matter, but they are perfectly soluble in caustic alkali, and the solution gives with acids a curdy precipitate. They are considered, therefore, as composed of condensed membrane, or in chemical language, of albumen.

Other hard parts are rigid, considerably harder than

the former; when dry, and in many cases when wet, they are very slightly flexible or elastic, and when struck by a hammer or when bent beyond their power of resistance, break short with a splintery surface. When exposed to a red heat with access of air, the membranous or animal part is destroyed; but the earthy part remains in sufficiently abundant quantity to retain the external form and generally the internal structure of the entire substance, of which calcined bone and calcined oyster-shell are examples. The original hardness of these parts is owing to the abundance of earthy matter that enters into their composition. When such parts are on the outside of the body they are called in common language, shells horns teeth, according to their position and the uses for which they seem intended. When they occur within the body they are called bones.

If however we restrict the term bone to its common meaning, we shall exclude the horns of the stag kind and the substance which forms the body of most teeth, both which are truly bone, and shall include some substances, such as cuttle-fish bone, which is truly shell.

It is therefore necessary to enter into a more minute examination and comparison of these hard substances in order to ascertain which of them are shell and which bone; and, as the result of our inquiry, we shall probably find with respect to this class of natural bodies as with many others, that although the two extremes of the series are readily enough distinguishable from each other, yet they approach by such insensible inter-

mediate gradations as to render it impossible to say where the one begins and the other ends.

There is a class of shells, comprising most of the univalves, which are harder than other shells and when broken present thick parallel layers, the layers themselves having usually a finely fibrous structure at right angles to the external surface. These fibres may often be seen to be nothing more than the transverse section of thin transparent parallel lamellæ, which when viewed on their broad surfaces often exhibit the usual natural joints of calcareous spar. When such a fracture is viewed by the naked eye, it has a good deal the appearance of porcelain,—whence their name of porcellanous shells. When carefully cleansed from all remains of the animal which inhabited them, they give out scarcely any perceptible odour on being made red hot though their colour becomes somewhat gray. When unaltered they dissolve in dilute acid with much effervescence of carbonic acid gas, and a few hardly appretiable gelatinous flocks remain undissolved. These latter on being collected and washed, give out when heated a faint odour of burnt animal matter and become black before they are consumed. By proper chemical tests the soluble part of the shell is proved to have been carbonate of lime or chalk, the particles of which were cemented together with a very minute portion of animal mucus.

Another class of shells is the nacreous, so called from the varying and iridescent colours that they exhibit resembling those of nacre or mother-of-pearl; this very substance being, indeed, only a part of a nacreous shell.

These when heated in a crucible give out the odour of burnt feathers, often with a perceptible smoke, become of a dark-gray colour, and when submitted in this state to the action of acids, there remains undissolved a notable quantity of charcoal. In the recent state they effervesce with weak acids, and when the calcareous matter has been removed, there remains a series of flexible membranous or semigelatinous lamellæ, lying parallel to one another and representing the form of the entire shell. These lamellæ have sometimes a distinctly fibrous structure parallel to the surface of the shell; and though quite flexible while moist, they shrivel on drying and become hard like horn,—a substance to which they bear the greatest possible analogy. The nacreous shells therefore are always very finely lamellar in structure, and are represented by some as composed of alternate layers of membrane and carbonate of lime; but the more probable opinion is, that the calcareous matter is intimately mixed with the membrane rather than distinct from it. These shells increase in size, in order to accommodate themselves to the growth of the animal, by the deposition of new and larger layers from within; and hence the external surface is covered by concentric furrows or wrinkles marking the outer margin of each successive layer.

Between the two classes of shells that I have described are others the minute structure of which I am ignorant of, but which differ considerably in the proportion and condition of their membranous ingredient.

Thus it appears that all shells, how much soever they may differ from one another in structure, agree in containing carbonate of lime as their only earthy ingredient, and an animal substance nearly resembling if not identical with horn or membrane, as their consolidating or agglutinating ingredient.

Exactly the same substances, namely carbonate of lime and membrane, in various proportions, form the constituent materials of the madrepores and other hard corals.

On examining the hard covering of aquatic crustaceous animals, such as the crabs and lobsters, we find, after the action of acids, that there remains a whitish soft elastic cartilage which represents the original shape of the part, and that the acid solution not only contains lime that had been in the state of carbonate in the original shell or covering, but likewise phosphate of lime although in smaller proportion than the carbonate. The presence of this earthy salt forms an essential difference in chemical composition between proper shell and the covering of the crustacea, which latter substance may thus be considered as holding an intermediate position between shell and bone.

Some of the corallines, chiefly those belonging to the genera *Gorgonia* and *Antipathes*, approach still nearer in chemical composition to bone; and indeed are hardly to be distinguished from it, their earthy part being phosphate of lime with only a small admixture of carbonate, their figure and structure being represented by dense membrane, and, when boiled, they give out a notable quantity of true jelly, which

like other kinds of animal jelly, has the property of forming a precipitate with infusion of galls or of oak-bark.

The proportion of membrane in these substances varies considerably, so that while one species almost exactly agrees in composition with the horn of the stag, others contain so much membrane in proportion to earthy matter as to be nearly identical with the bone of the cartilaginous fishes.

If a piece of true bone in an unaltered state be put into weak acid (muriatic acid on the whole is the best), a moderate degree of effervescence will take place, showing the presence of some carbonate. By a continuance of this process for some days all effervescence and chemical action will cease: what remains undissolved will still represent the size and form of the original bone; but it will be semi-transparent, will exhibit a distinctly cellular structure, will be soft flexible and to a certain degree elastic. If, after being washed, it is boiled in water, it will be found to be in part soluble; and the solution when boiled down to a proper consistence will become viscid, will gelatinize on cooling, and by drying will be brought to the state of hard glue. This jelly, when again dissolved in water, will become curdy and will give a gray precipitate with nutgall, and will exhibit all the other physical and chemical properties of gelatin: the remaining portion insoluble in water will become hard and somewhat brittle by drying, will burn in the fire like a piece of horn, will dissolve in caustic fixed alkali forming a saponaceous

liquid, and will show all the other properties of albumen or membrane.

The acid in which the bone was first steeped will give an abundant white precipitate of phosphate of lime by means of caustic ammonia, and will give a much smaller precipitate of carbonate of lime by carbonate of ammonia. Thus by the action of a few simple re-agents the essential constituents of bone are demonstrated. In this summary I have taken no notice of the oil or fat which is contained in the internal bones of all mammiferous animals, because it seems to be by no means an essential part of bone; the horn of the stag and of other animals of the same kind being entirely free from it. On this account it is that hartshorn jelly, made by boiling the shavings of stag's horn in water, is often recommended to persons of very weak digestion in preference to other animal jellies as being absolutely free from oil; for, though hard fat is incapable of dissolving in jelly, yet the softer oily fats will combine with it in small proportion.

But although it is impossible to draw any marked line of chemical distinction between true bone and the indurated membranous textures that I have already mentioned, yet the mode of their origin furnishes a real and very important difference.

Of the organisation of coralline bodies, indeed, we know nothing; for scarcely any of them have been even superficially examined when alive, and, when dried, all trace of structure in the soft parts is completely obliterated.

But with regard to the production of shell both in univalve and bivalve testacea, we are certain that it never, as such, forms a constituent part of the living animal. A viscid fluid is secreted by certain organs, and it is only when discharged from the body that it assumes the consistence and other characters of shell* therefore, although we may with perfect propriety speak of the structure of shell as we speak of the structure (that is of the mechanical arrangement of constituent particles) of a crystal, it would be a gross misapplication of terms to speak of the organisation of shell; this latter meaning such an arrangement as is compatible with and necessary for the performance of vital functions. Shell is essentially a dead body or rather one which never was alive; for though naturalists and collectors well know the difference between what they call a dead shell and another, they mean by this expression merely to point out the difference between an empty shell and one the inhabitant of which was alive at the time of its capture.

The way in which the hard covering of the crustacea is annually formed (for these creatures change their shell every year) has not been sufficiently examined to ascertain whether it is at first a mere exudation which hardens out of the body of the animal, or is an induration of the cuticle by the deposition in its pores of calcareous matter conveyed thither by

* If a small part of the shell of the common garden snail is removed, the bare place soon becomes covered with a viscid exudation which by degrees hardens into shell apparently of the same kind as covers the rest of its body.

proper secreting vessels. If the former is the case, the shell of the crustacea is analogous to that of the testacea; if the latter, it somewhat resembles bone in the mode of its formation.

With regard to bone itself, there is no doubt that it is as truly organised and vital as any other part of the body. As soon as the rudiments of a young animal can be distinguished before its birth, the place of the future bone is indicated by a soft or semi-fluid matter inclosed in a delicate membrane: by degrees both the membrane and the matter which it incloses become more dense and cartilaginous; opaque white spots then appear which soon after are penetrated by vessels carrying red blood: the deposition of bone then begins and at the same time the cartilage seems to be gradually replaced by membrane. The rudimental bone which at first was solid, now begins, at least in the long bones, to exhibit an internal cavity or hollow axis; thus showing that, while fresh matter is continually depositing to supply the growth of the bone, that which had been already deposited is removed and that this latter process takes place in the interior of the bone at a greater rate than the other does. The activity of the two vital processes of deposition and removal, or, to speak in technical language, of secretion and absorption, is of course proportioned to the rapidity of growth; so that during the early periods of life the bones participate with the soft parts of the body in the continual change and flux that is taking place within them. When the full stature of the animal is attained these two actions probably di-

minish in rapidity, but still are kept up sufficiently to preserve the life of the part. As old age approaches, the removal of the earthy ingredient of bone seems to become more difficult; its proportion therefore to the membranous ingredient increases, and hence the bones of old animals are harder of greater specific gravity and more brittle than those of younger ones.

That very remarkable natural process, namely the annual renewal of the bony horns of the stag and other animals of the deer tribe, is perhaps the most striking example and illustration of the circumstances necessary to the formation of bone. These horns arise from a short process or pedestal projecting from a bone forming the upper part of the skull and called the frontal bone. At the season of the year when the horns are about to be renewed, an increase of vital action takes place in this bone, and a faint red line, indicating the presence of blood-vessels, will be perceived in making a longitudinal section of the bottom of the horn and the base on which it stands; the situation of this red line showing precisely the boundary between the dead horn and the live bone: absorption of part of the bone takes place which loosens the adhesion of the horn to it, in consequence of which this latter falls by any accidental shock which it receives. The spongy tissue of blood-vessels, which may now be seen covering the end of the bony base, is soon entirely covered by the growth of the external skin; and this may be considered as terminating the first part of the process. Soon afterwards a small tubercle arises from the end of the bone and presses

upwards the skin which covers it: the tubercle rapidly elongates, the skin extends with it, and in the course of a few weeks it has assumed the size and shape of the future horn: in this state it is covered by the attenuated skin, which latter has pushed out an abundant growth of short fine hairs resembling the pile of velvet. Beneath this skin is a layer of blood-vessels the diameter of some of which is equal to that of the little finger; these rest on a thin layer of dense membrane of the same nature as that which covers ordinary bones, and called the periosteum; and within the periosteum itself is a flexible cartilage, penetrated in all directions by ramifications from the blood-vessels already mentioned.

In this state the future horn is very tender and exquisitely sensible, it bleeds when the skin is broken, and the animal often suffers much in this part from the bites of gadflies and other insects. When the cartilage has attained its full growth, ossification begins by the deposition of phosphate of lime and goes on till the bone or horn has acquired its complete hardness. During this process, a ring of bony beads has been forming at the base of the horn in the intervals between which the main trunks of the blood-vessels lie: these beads enlarge by the continual addition of bony matter, and in so doing compress the adjacent sides of the blood-vessels and thus diminish the supply of blood; at length the sides of these vessels are quite squeezed together, circulation ceases, and all the soft parts die shrivel and dry up, and are rubbed off by the animal against the bough of a tree,

leaving the dead bone or horn attached by its base to the frontal bone; till, after some months, the time for shedding it again comes round, when a repetition of the processes already described takes place.

Bones even of the same animal vary much in structure and in hardness and no doubt in the relative proportion of their component parts, according to the situation in which they are placed and the use to which they are put. Thus the shafts of the long bones, being wanted chiefly for support, are more or less in the form of a hollow cylinder and the texture of the bone itself is dense and compact. Those parts of bones that form the joints or articulating surfaces by which one is hinged on to another require a considerable space for the joint and for the attachment of ligaments; but as a degree of strength proportioned to its thickness is not wanted the structure becomes cellular. A similar structure is observable in the flat bones, which consist of two thin parallel tables of dense bone having a cellular part interposed between them. Hence, in utensils made of bone, the compact cylindrical ones are generally employed both as being stronger and admitting of a more uniform and higher polish.

The bones of animals belonging to the same general class of nature are commonly observed to have certain points of general resemblance by which they may be distinguished from one another, and are applied by man to various uses corresponding with such differences. Thus, the bones of fishes are softer more flexible and contain a much larger proportion of jelly

and membrane, or, which comes to the same thing, a much smaller proportion of earthy matter, than those of the mammalia or warm-blooded quadrupeds; and the bones of these latter, comparatively dense and hard as they are, fall considerably short in density and hardness of the bones of birds, which however are generally too small and thin to be applied to much use in the arts.

Bone undergoes, much more slowly than the soft parts of animals do, the process of spontaneous decomposition; meaning by this term that disintegration of a compound which takes place either by the chemical reaction of its ingredients on one another, or by means of air and moisture at common temperatures. The bones of a human body buried in a churchyard are perhaps mostly consumed in twenty or thirty years; yet under favourable circumstances they will endure for a much longer time with but little change. Thus, in the charnel-house at Morat in Switzerland, there still remain many bones of the soldiers of Charles the Bold's army who perished there in 1438 being 401 years ago. When Sir Christopher Wren was rebuilding St. Paul's Church after the great fire of London, the workmen in digging for the foundations came to the floor of a Roman temple dedicated to the goddess Diana, on which were the horns of stags and bones of other animals. Tombs of the ancient inhabitants of this island are occasionally opened in which are found bones that have been deposited there during many centuries; and I have the pleasure of exhibiting to you part of a carved bone spoon (dis-

coloured and passing to a state of decomposition, it is true) which was found in an Etrurian tomb at Vulsinum in Italy, possibly as ancient as the foundation of Rome. In the valley of the Lea are many peat mosses, the remains of ancient forests, now covered to the depth of several feet with alluvial silt. Many of these have of late years been dug into on occasion of making docks and other excavations; and in or upon them have been found the osseous remains of boars stags and other animals, which have lain there from the time that these creatures roamed wild in the immediate neighbourhood of London. Not only the remains of individuals belonging to species now extant are still found after being buried for centuries, but the bones of species now extinct and many of which, judging from the habits of species nearly allied to them and now living, can scarcely exist except in warm climates, are found abundantly in the British islands and in all parts of Europe. Remains of a large animal of the ox tribe are found in Essex. Elephants hippopotamuses and rhinoceroses, differing in some respects from any now known to exist, are also found in the same county and in other places near London. Hyænas and tigers also of extinct species occur in the cavern of Kirkdale in Yorkshire, and in other caverns in the west of England; and in certain caverns in Germany are found the remains of two species of bear, differing in some anatomical details from any known living species of the same genus. There is no evidence that the human race was contemporary with these creatures; and yet, notwith-

standing the enormous length of time that must have elapsed since the deposit of the animals in the places where their bones are now found, many of them are in a state apparently of almost perfect preservation. Membrane and jelly still remain in the bones; but the oil or fat, being uncombined with earthy matter, has disappeared.

In what I have hitherto said, I have alluded very slightly to the use of bone in the arts which was the ostensible object of the present illustration; for I confess that I have not unwillingly been tempted to enter into the preceding physiological and other details in order to relieve the dryness of mere technical description. In what remains I shall treat of the practical part of my subject, beginning with an inquiry into the use of bones as articles of food.

All animals that eat flesh will likewise eat bones, provided they are of a size to be easily crushed and masticated by them; so when a lion or tiger has taken one of the smaller antelopes, I presume he devours many of the bones along with the flesh, leaving only the spine skull and horns. But when he has pulled down a horse or buffalo the case is different; the flesh alone of the animal is sufficient for an ample repast; the leg-bones and ribs are not to be cracked by a single straightforward crush of the jaw; and the spine, from its awkward shape as well as by reason of the strong ligaments by which its parts are bound together, may well resist the lazy efforts of an animal already satiated with food,—not to mention that the great length of the canine-teeth

in the larger animals of the cat kind as well as the small number of their grinders, render the act of gnawing both difficult and unnatural to them. The half-picked carcass therefore falls to the share of the wolves and hyænas. The former, after tearing off the ligaments of the joints proceed to separate the bones from each other; and then, by gnawing, grind off the softer parts of the spongy articulating surfaces in which they find a wholesome food. The hyæna, with far greater strength of jaw and of teeth than any other animal of his size, goes to work bodily, especially on the ribs and other flat bones, crushing them into large splintery fragments and swallowing them in this state without fear of being choked or injured by their sharp points and rough edges. These two animals therefore (including the dog as a sub-species of wolf) are eminently the bone-eaters: the membranous and gelatinous matter of the bone, being dissolved out by their gastric juice from the earthy portion, undergoes the usual process of digestion; while the latter apparently unaltered passes through the intestinal canal, giving to their excrements the well-known appearance of half-dried mortar, and may afterwards be applied to all or any of the purposes for which bone-earth is used.

Man, the cooking animal, extracts nutriment from bones in a different way. When very hard pressed indeed he can stave off famine for a while, as Captain Franklin and his party did more than once in their exploratory arctic expedition, by taking bones which even the wolves had left, and scorching them so as

in some degree to subdue their hardness and thus render it possible to gnaw and masticate them as a succedaneum for food, or, at least, as some alleviation of the agonies of famine.

But the animal matter of bones is best extracted by hot water. Every housekeeper knows that the nutritive quality of meat soups is much increased by boiling the bones together with the meat. In this way however only a small proportion of the food contained in the bones is made available; for part of the gelatine is with difficulty, and the membranous part is not at all, soluble in common boiling water: much even of the fat is locked up in cells of the bone from which it cannot escape except these cells are broken into.

The solid part of the long bones contains very little soluble matter; it would therefore in most cases be a matter of economy to exclude them; the advantage to be derived from them by ordinary treatment not being equal to the value of the fuel which they would require. It is from the enlarged extremities of the long bones and their articulating surfaces that the principal supply of nutritive matter is to be derived: these parts therefore should be sawed off from the rest and broken into pieces. From the bones of young animals thus treated boiling water will, in two or three hours, extract the whole or nearly the whole of the soluble matter: but, in the bones of older animals, the gelatine seems to be in a state of condensation approaching to that in which it exists in skin, and therefore requires the long-continued action of

boiling water for its separation. By way of experiment, I had the leg-bone of an ox sawed longitudinally and boiled for three or four hours. At the end of this time, the whole of the fat and mucus had been extracted with part of the jelly. On applying the finger to the cellular part of the bone when wiped dry I found the surface to be considerably sticky, and, on examining the cells, I found many of them completely filled with a transparent substance scarcely viscid, but much resembling pieces of glue that had been put to soak in cold water; by which, as every one knows, the glue swells exceedingly by absorption of the water without however becoming viscid. A second boiling for three or four hours in fresh water dissolved out a considerable proportion of the gelatine; but still the surface of the bone remained sticky, many of the cells had a glazed surface, and even after a third repetition of the boiling only a few even of the superficial cells were quite empty. It is evident therefore that we cannot avail ourselves, with any regard to economy of fuel, of the whole of the nutritive matter contained in bones by the action of boiling water applied in the common way. But by means of a digester—that is, a boiler with a steam-tight cover and a safety-valve—we can without hazard raise the temperature of water from 212° its boiling point in the open air, to 270° or 280°. At a less heat than even the former of these not only the condensed gelatine but also the membranous part of bones is dissolved, if the bones have previously been reduced to small pieces, and the undissolved residue will be found to be a

friable crumbling mass with scarcely any remains of animal matter. It appears that bone soups are thus prepared at present at some of the hospitals and military head-quarters in France, and memoirs have been published stating the advantage of making a collection of dry bones as part of the provisions of a garrison in case of siege, being a kind of food scarcely susceptible of decomposition or of destruction by rats or mice, and which would require no other magazine than simply making them into stacks and covering them with a roof of thatch or any other material. Complaints, it is true, are made of the burnt flavour which such soups are liable to have, and perhaps it may not be very easy to regulate the temperature of the water in the digester so as to avoid the empyreumatic flavour and at the same time completely to extract from the bones the animal matter. On this account it is that another scheme has been proposed, namely to put the bones, after soup has been made of them by boiling in the common way, into a stone trough and then pour on them very dilute muriatic acid. By repeating this process in the cold a sufficient number of times, the whole of the earthy matter will be dissolved out and probably without much, if any, injury to the animal matter which will remain in the form of a porous membrane: by repeated percolations of water the acid would be washed out; or if a little should remain, a last sprinkling with a solution of carbonate of soda would convert the acid into common salt. The membrane being now dried in the air will acquire a horny hardness, by which it will be rendered almost incapa-

ble of spontaneous decomposition and would probably be found to be much more easily convertible into palatable human food by the common processes of cooking than the entire bone. The plan, to say the least of it, is plausible, provided muriatic acid may be had, as it now may be, at a very small cost.

There is however a whole class of animals, the bones of which without any chemical preparation are presented to us by nature in a state capable, with very little trouble, of being converted into nourishment. I mean the whole class of fishes. These are divided by naturalists into two tribes the cartilaginous and the spinous. Of the former the bones when recent are in a soft cartilaginous state, as those of the skate and sturgeon; and even those of the spinous tribe contain so little earth, that, by drying and grinding them, a powder is obtained which, when made into cakes with meal, has proved a valuable resource to the people of Norway and Sweden in times of scarcity; and some of them, as those of the mackerel, by simply browning on a gridiron become quite friable, and when treated with a proper quantity of pepper and salt form a very palatable article of food.

With regard to the mechanical uses of bone, it may be observed that the spines in the back-fins and tail of certain fishes, especially the serrated tail-spine of the sting-ray and of some others of the same species, from their size sharpness hardness and toughness, have been used for pointing arrows or spears by some of the ancient nations, as they are at present by many savage tribes, forming weapons of the most formidable

description, from the jagged lacerated wounds which they produce. The serrated teeth of sharks inserted on the edge of a staff of heavy wood, afford another instance of animal bone, unchanged in figure by the use of any tool, being employed as the essential part of offensive arms.

The interior bones of animals are also used for the same purpose; but to adapt them to this use they require to be fashioned by rasps and other tools into simple or jagged points. Fish-hooks are also very ingeniously made of the same materials by the inhabitants of some of the South Sea Islands as well as by the Esquimaux. The latter people, indeed, from their almost total want of wood are obliged to find substitutes for it in the bones of whales and the tusks of the walrus, which accordingly are the material of many of their domestic and other implements. Bone when thin has a considerable degree of elasticity; and this property is ingeniously taken advantage of by the Esquimaux in their fish-spears.

The bones of fine texture, especially the teeth or tusks of the hippopotamus the elephant the walrus and the narwahl, are an excellent material on which to exercise the arts of carving or sculpture, and of turning in the lathe; and which has been taken advantage of by many nations in very different states of civilisation. Phidias is said to have used ivory, among other materials, in fabricating the colossal statue of Minerva at Athens; but ivory was not a material on which the sculptors of ancient Greece were fond of exercising their skill.

The Romans seem to have used ivory rather as a material for inlaying and otherwise ornamenting furniture than for sculpture. The artists of India and China have immemorially been celebrated for their exquisite and intricate sculptures of ivory and bone; and specimens of beautiful chain-work in the same material illustrate the skill of the artists of Archangel. Other northern tribes of the Russian empire amuse themselves, probably during the long leisure of their winters, by representing in rude sculpture the bear the fox and other wild animals of the polar regions. In our own country ivory and bone are not sculptured but are turned in the lathe or fashioned by means of other tools into various articles of ornament and use. Thus, tooth and nail-brushes, handles of knives, combs paper-knives and a variety of smaller articles are made of ivory or bone, the latter of which has the advantage of being harder whiter and little liable to become yellow with age, and, when employed on small objects, may be had of a grain nearly as fine as ivory.

The scrapings shavings or sawdust of bone is an article that bears a good price in the market, being much used by pastrycooks and others as a material for jelly, which it readily gives out to boiling water. The jelly thus produced is probably quite as good as that from calf's foot; and the shavings, when dry, have the advantage over calf's foot of not suffering any change by keeping. Another use of considerable importance to which bone-shavings are applied, is in case-hardening small articles of steel.

Bones have always been used as one of the ingredients of that multifarious mixture of offal of all kinds—a dunghill; but it is only of late years that their extraordinary value as a manure has been fully ascertained. About forty years ago an acquaintance of mine was cultivating a small estate of his own, and from not having been originally brought up to farming was the more ready to try novel experiments. A pack of hounds was kept in his neighbourhood; and this furnished him with an opportunity of obtaining at small cost the bones of the old horses and other animals that were slaughtered for food to the dogs. He invented or got made for him, a machine for crushing the bones; and then spread them as a top-dressing on a grass field, the soil of which was a sour red clay that produced nothing but dyers'-broom and the other weeds that usually grow on such soil along with the coarsest grasses. The effect produced by the bones was strikingly evident in the next spring: the dyers'-broom and other weeds had mostly disappeared, and were succeeded by a close undergrowth of clover and fine grasses. The animal matter of the bones no doubt contributed much to this striking amelioration; but the earth of the bones, especially the phosphate of lime, also bore its share in it. Many of our limestones are little else than a congeries of the organic remains of corals and other animals; and the late Professor Turner detected the presence of phosphate of lime in the Saurian remains that abound in the lias limestone. Many of the corallines, as I have already stated, contain as much phosphate of lime as

the bones of mammalia do: it is probable therefore that in the coralline limestones also phosphate of lime might be found if it was specially searched for; and to the presence of this, if authenticated, may perhaps be attributed some of the effects on vegetation which agricultural chemists are in the habit of accounting for by the action of caustic lime or of its carbonate.

I do not know if bones are valued as a manure in any part of the continent of Europe; but it is certain that of late years they have attracted in a very particular degree the attention of the English farmer. Bones are collected in the streets of London and other great towns, and after being sorted, those that are not required for other purposes are used as manure. In the Thames above London Bridge may almost always be seen a few sloops and cutters, chiefly from Hull, which are occupied in this trade. They take the bones on board generally in a more or less putrid state and stow them in bulk in the hold: here they soon begin to ferment, giving out an odour by which the bone-ships are detected at a considerable distance; and when the cargo is discharged at Hull it is frequently reeking and smoking hot from decomposition. This probably softens the texture of the bones, and renders them more easy to be crushed in the mill through which they are passed previous to disposing of them to the farmers. They are employed chiefly in two ways, either as a top-dressing to grass land or are drilled with turnip-seed, the plants from which, under the stimulating effect of this powerful manure, quickly pass through their first stage into the rough

leaf, and thus in a great measure avoid the attacks of the *fly* and other insects by which young turnip-plants of tardy growth are often entirely cut off. Our native supply of bones is not at present sufficient to answer the large and increasing demand for them for agricultural use; and bones are now imported from South America* and other parts. It is even said that some of the celebrated battle-fields of our own time have furnished considerable supplies of this now valuable commodity.

I now proceed to describe the action of heat on bones; first in the open air, and secondly in close vessels.

If we throw into the fire a bone, even of the most solid kind and from which all oily matter has been carefully separated (an old tooth-brush will serve for an example) it will be found first to crack, and then to burn with a large and bright flame in consequence of the combustible gases into which the animal matter of the bone is in part resolved. If the bone is taken out of the fire as soon as it ceases to flame, it will be found to be of a bluish-black colour from the charcoal which is the residue of the decomposition of the animal membrane. If the blackened

* "In the neighbourhood of the great towns on the shores of the Plata the number of bones strewed over the ground is truly astonishing. Since our return I have been informed that ships have been freighted to this country with a cargo of bones. That cattle should be fattened on turnips manured with the bones of animals that lived in the southern hemisphere is a curious fact in the commerce of the world."—C. Darwin, p. 157.

bone be returned to the fire, the whole of the charcoal is at length consumed, and nothing remains but the white earth of the bone commonly called bone-ash.

If instead of a single one a heap of bones is employed, and a fire is kindled in one part, it will spread by degrees to the whole heap giving out more or less flame and a strong heat; and in the treeless steppes of Tartary and the pampas of South America the inhabitants make up for the want of other fuel by burning the bones of their cattle, it being considered that the bones of an ox will produce heat enough to cook its flesh by. This therefore is another to be added to the many uses of bone. But by burning bone in an open fire no other product is obtained from it except the ashes, while the horribly noisome odour of the gas which escapes combustion renders this process a sore nuisance in any inhabited neighbourhood.

The decomposition of bone by heat in close vessels, whereby the action of atmospheric air is excluded, is well worthy of minute attention, both in consequence of the large scale on which it is carried on as a process of chemical manufacture, of the importance of the products obtained and of the interest which it possesses in a scientific point of view. I shall therefore conclude this evening's illustration by examining this part of my subject with some minuteness, avoiding as far as I can mere chemical details as being little suited to a miscellaneous audience.

The animal matter of bone is the only constituent part of this substance susceptible of decomposition by

a heat brought up to low redness; in considering therefore the action of close heat on bone the earthy ingredients may be regarded as passive. The animal matter is either a substance analogous to skin, or is a mixture of membrane and jelly: the former opinion is supported by some of the most eminent modern chemists, but it is of no sort of importance to our present purpose which opinion is adopted as all three substances are composed of the same ultimate elements and nearly in the same proportions. The four simple substances, then, of which the animal matter of bone is composed are carbon hydrogen nitrogen and oxygen; and of these the three latter, when in an uncombined state and at the usual temperature and atmospheric pressure, are in the form of gas. Now, when it happens that three substances habitually gaseous are combined with one naturally solid, and when these four substances are likewise capable of uniting together by twos and threes, or in other words, of forming binary and ternary compounds, the attraction that holds together all the four is easily disturbed by a moderate increase of temperature; in consequence of which the same elements by arranging themselves differently produce two or more different substances.

This is the case in the present instance. On exposing bone shavings even to a lamp heat they are observed immediately to become black; showing that the new compounds that are the result of this decomposition are not capable of combining with the whole of the carbon, but that part remains in the state of

charcoal intimately mixed with the earthy matter. This mixture goes by the name of bone-black or animal charcoal, the uses of which I shall detail by and by.

Part of the carbon combines with part of the oxygen and forms carbonic acid, while part of the hydrogen and part of the nitrogen produce ammonia; the carbonic acid and the ammonia, in proportion as they are formed, combine and produce carbonate of ammonia, which therefore is another of the useful substances resulting from the decomposition of bone. Part of the oxygen and hydrogen combine and produce water; and part of the oxygen the hydrogen and carbon, by combining, produce a volatile oil of a strong and peculiar odour which goes by the name of animal oil. The remainder of the carbon and hydrogen, with probably some nitrogen, combine and produce an inflammable gas. Thus the decomposition in close vessels of the single substance, bone, produces five new substances; namely animal charcoal, carbonate of ammonia, animal oil, water and an inflammable gas. A low red heat volatilises all these substances except the first; which therefore when the process is performed on a large scale in iron vessels remains in the retort separated from the other four compounds. The water the carbonate of ammonia and part of the oil are condensed and remain in the receiver; the inflammable gas, holding in solution another part of the oil from which it derives an inconceivably nauseous odour, passes off through a pipe and is either conveyed into the ash-pit of the furnace whence it is drawn up among the

burning fuel and is consumed, or is set fire to as it issues from the mouth of the pipe; by either of which methods its noisome smell is for the most part avoided. The ammoniacal liquor likewise combines with a little of the oil, from which it may for the most part be separated by redistillation; enough however of the oil remains united with it to produce that particular modification of odour by which spirit of hartshorn (for so this substance is commonly called) is distinguished from pure ammonia; or, by other processes unnecessary here to mention, the ammonia is obtained entirely free from the oil.

I now return to the animal charcoal which I have already briefly mentioned. When obtained from bone it is called bone-black; when from ivory ivory-black; the difference between these two being merely that of texture and some slight tint of colour, for they both are an intimate mixture of carbonate and phosphate of lime with charcoal resulting from the decomposition of animal matter. Till of late, the only use to which this substance was put was as the basis of black pigments, ivory-black having been first so applied by the celebrated Greek painter Apelles.

Some years ago, a German chemist of the name of Lowitz settled at Petersburg, discovered that common charcoal when fresh burnt and in fine powder has the property of taking away the colour of common vinegar and of several other liquids, and likewise of removing the odour proceeding from vegetable and animal substances in a state of spontaneous decomposition. This interesting and valuable fact was soon applied to the

clarification of various liquors in pharmacy, and as an auxiliary in the art of refining sugar. About the year 1811, M. Figuier of Montpellier, ascertained that charcoal from animal substances not only is equally efficacious when used in considerably smaller proportion than vegetable charcoal, but that it is capable of decolouring many liquors on which the latter has no sensible effect whatever. This discovery created immediately a demand for bone-black in this country and in all the other manufacturing countries of Europe, those especially in which refined sugar is obtained either from brown cane-sugar or from the juice of the beet. A considerable difference in efficacy was soon perceived between different parcels of bone charcoal; and chemists of no mean name set themselves to work in order to discover the theory of the decolouring action of charcoal, and some method if possible of increasing the efficacy of the inferior varieties of it. It is certain that the more finely divided any given weight of the charcoal is, the more powerful is its decolouring effect; and thus the inferiority of those kinds of charcoal that break with a glossy fracture when compared with those of a dull fracture is accounted for: the particles of the former being assumed to be nearly solid and those of the latter to be porous, or in other words, more minutely divided. In bone charcoal the carbonaceous particles are separated from each other by the large quantity of earth with which they are mixed, and hence the superiority of this to vegetable charcoal seems to resolve itself into a case of very minute division. Still however the question

remains to be answered, What kind of action chemical or otherwise is it that exists between charcoal and certain colouring and odorant substances; and what is the nature of the compounds or mixtures resulting from this action? It has been ascertained as a fact, though the reason is yet to seek, that wood charcoal ground to fine powder and then mixed with carbonate of potash and exposed to a red heat, becomes, after the alkali has been washed out from it, nearly as efficacious as bone charcoal; and that this latter by a similar treatment has its clarifying power greatly increased.

For many uses the presence of the earthy part of bone charcoal is no hinderance, but in those cases in which it would be inconvenient or injurious, it is necessary to steep the charcoal, previously pulverised, in dilute muriatic acid for a day or two, by which the whole of the earth will be dissolved and may be separated by filtration and subsequent washing from the merely carbonaceous part, which will be found to have sustained no deterioration of its clarifying power by this treatment.

A few words yet remain to be said concerning the earthy basis of bones. This, as I have already stated, is a mixture of carbonate and phosphate of lime the latter salt being in by much the largest proportion.

Many are the uses to which bone-ash is applied. When ground to moderately fine powder it is the material of which the cupels of the gold and silver assayers are made, being at the same time very infusible and sufficiently porous to absorb the litharge and

other impurities, while the fine metal remains on its surface.

When levigated and washed over, it forms an exceedingly useful polishing powder for plate and other articles. It is likewise the only material from which phosphorus is at present prepared. Part of the phosphoric acid is separated by the action of sulphuric acid from the lime with which it is combined in the bone-ash; and this portion, when mixed with charcoal powder and strongly heated in an earthen retort, is decomposed; the phosphorus is liberated in the form of vapour and is consolidated by coming in contact with the cold water in which the beak of the retort dips. It is afterwards purified by filtration through leather in hot water and is finally melted, likewise under water, in conical moulds, by which it assumes the usual appearance of stick phosphorus.

Many are the things thrown away as useless which, when circumstances allow of their being collected in considerable quantities, are found to be applicable to a variety of useful purposes; and in none is this observation more remarkably exemplified than in the subject of the present illustration. I have shown that bone contains a considerable quantity of valuable nutriment, which may be extracted with greater or less ease in proportion as its cohesion is more or less overcome — that in its entire state it forms excellent handles for small brushes and is also applicable to a variety of other similar uses—that the worker in steel employs it for case-hardening small and delicate articles — that, in proportion to its weight, it is the most

valuable and active of all manures and contributes in no inconsiderable degree to improve and increase the agricultural produce of all the districts where it is employed—that, in the absence of other combustibles, it may be and is largely used as fuel in the plains of Tartary and South America—that, by its decomposition in close vessels, it produces hartshorn ammonia and animal charcoal—and that, when burnt to ashes, it becomes useful to the assayer furnishes a valuable polishing powder and is the material from which phosphorus, that curious and interesting substance, the most combustible of all solids, is produced.

VII. ON HORN TORTOISESHELL AND WHALEBONE.

The subject of the present evening's illustration is the manufacture of horn and of tortoiseshell, to which I shall add some particulars respecting whalebone — a substance which in its physical and chemical properties bears a great resemblance to horn.

In the English language we have only one word to express two quite different substances — namely the branched bony horns of the stag genus, and the simple laminated horns of the ox genus and other kindred genera.

The bony horns are called in French *bois* from their likeness to the branch of a tree: they are annually renewed, and are peculiar to the male sex except in the reindeer the females of which likewise have horns though not nearly so large as those of the male.

The other sort of horn, to which the French appropriate the term *corne* and which is the subject of our present inquiry, is found in the ox the antelope the goat and sheep kinds. These are never branched or palmated but are always of a simple conical figure more or less curved, and in some of the antelopes

spirally twisted: they are found in both sexes, but in the goats and sheep are much larger in the male than in the female.

In all these animals, a bony core of a loose texture and conical figure rises from the bone of the forehead, covered by a permanent vascular membrane from the surface of which are produced or secreted thin layers of horn in constant succession. It is supposed that one layer, or rather one set of layers, is produced every year; but as the former layer remains closely adherent to the new one, such horns are permanent, lamellar in texture, and exfoliate only very slowly from the outside by exposure to weather and friction. The structure of such horns is that of a number of cones or sheaths inserted into one another, the inner of which lies on the vascular membrane that covers the bony core or base. The tip of the horn—namely, that part which projects beyond the core—is very dense and the layers of which it is composed can hardly be distinguished, whereas the lower parts are of a looser structure, and the layers may readily be seen from the successive terminations of them forming prominent rings which are very observable on the lower part of the horn. Horn itself is quite insensible like the finger-nail; and therefore the tip may be cut off while the animal is alive without giving any pain; but if the section is made so low down as to include any part of the core, blood follows and the animal seems to suffer greatly.

But it is not merely in the defences projecting from the forehead of the genera already mentioned that

horn occurs: in the form of nails claws or hoofs it protects and arms the extremities of the toes in all warm-blooded animals and constitutes the leg-spurs of the cock and other gallinaceous birds. In the form of scales it covers the body of the pangolin of the armadillo of the lizard and serpent tribe and of most fishes, and incloses the tortoises in a kind of plate-armour. It also supplies the hairy covering of the land mammalia, from the fine down of the beaver to the bristles of the wild boar the horny hair of the elk and the musk and the spines of the hedgehog and porcupine. The horn of the rhinoceros is not formed on a bony core but is merely an aggregation of flattened hairs or bristles adhering by their sides, and presenting longitudinal pores or interstices of considerable magnitude at the base of the horn, and which become smaller towards the point; these interstices in the live animal are filled with a pulpy matter. All feathers likewise, from the plumes of the ostrich to the quills with which we write, and the wing-spurs of the cassowary, are only modifications of horn; so that it may be considered as the general covering of the most highly organised animals.

Horn also occurs, where it would not at first be looked for, in the form of plates hanging down from the palate or roof of the mouth in the Greenland whale and in those other cetaceous animals that are destitute of teeth. This modification of it goes by the common name of whalebone, of which I shall speak more at large hereafter.

The membranous parts of the animal body are also

exceedingly similar to if not identical with horn both in structure and chemical composition: such is the cuticle or scarf-skin which covers the whole body and separates from the true or sensitive skin on the application of a blister. The intestines the bladder and other thin parts which on drying become hard and transparent, are also of the same kind; as likewise are the air-bladders of fish: but these latter also contain jelly.

Certain animal fluids also bear a close analogy to horn in their chemical composition: such are the serum of blood and the white of egg. Both these substances coagulate at a heat less than that of boiling-water, and when afterwards dried at the common atmospheric temperature, become yellow transparent hard and bear a perfect resemblance to horn except that their texture is compact not laminated.

To all the substances above enumerated chemists give the general name of albumen; and it is distinguished by the following properties from jelly and from fibre the two other principal organic elements of animal bodies. It does not dissolve in boiling water and fix on cooling, as jelly does, and by its long resistance to putrefaction it is distinguished from fibre. I may also mention that, when exposed to a decomposing heat in close vessels, it produces a large quantity of that gaseous compound which forms the base of prussic acid; on which account it is that hoofs and the refuse parts of horn are in great request among the manufacturers of Prussian blue.

Almost the only kinds of horn that are the subject

of manufacture are those of the bull and cow, and the hoofs of these animals; the horns of the bullock, being thin and of a very coarse texture, are used only for the most ordinary purposes. Our domestic supply is by no means equal to the demand, so that great quantities are imported from Russia the Cape of Good Hope and South America.

The first process is the separation of the true horn from the bony core on which it is formed: for this purpose the entire horns are macerated in water for a month or six weeks according to the temperature; during this time the membrane which lies between the core and the horn is destroyed by putrefaction, so that the core becomes loose and can easily be extracted. The cores are not thrown away but are burnt to ashes, and in this state form the best material for those small tests or cupels employed by the assayers of gold and silver.

The next process is to cut off with a saw the tip of the horn, that is, the whole of its solid part, which is used by the cutlers for knife-handles, is turned into buttons and is applied to sundry other purposes. The remainder of the horn is left entire or is sawn across into lengths according to the use to which it is destined. Next, it is immersed in boiling water for half an hour by which it is softened; and while hot is held in the flame of a coal or wood fire, taking care to bring the inside as well as the outside of the horn, if from an old animal, in contact with the blaze. It is kept here till it acquires the temperature of melting lead or thereabouts, and in consequence becomes very

soft. In this state it is slit lengthways by a strong-pointed knife like a pruning-knife, and by means of two pairs of pincers applied one to each edge of the slit, the cylinder is opened nearly flat. These flats are now placed on their edges between alternate plates of iron half an inch thick and eight inches square, previously heated and greased, in a strong horizontal iron trough, and are powerfully compressed by means of wedges driven in at the ends.

The degree of compression is regulated by the use to which the horn is to be afterwards applied: when it is intended for leaves of lanterns, the pressure is to be sufficiently strong (in the language of the workmen) to break the grain: by which is meant separating in a slight degree the laminæ of which it is composed, so as to allow a round-pointed knife to be introduced between them in order to effect a complete separation.

The plates thus obtained are laid one by one on a board covered with bull's hide, are fastened down by a wedge and are then scraped with a draw-knife having a wire-edge turned by means of a steel rubber; when reduced to a proper thickness and smoothed, they are polished by a woollen rag dipped in charcoal dust, adding a little water from time to time, then are rubbed with rotten-stone and finished with horn shavings. The longest and thinnest of the films cut off by the draw-knife, when dyed and cut into various figures, are sold under the name of sensitive Chinese leaves (being originally brought from China) which, after exposure to a damp air, will curl up as if

they were alive when laid on a warm hand or before the fire.

For combs, the plates of horn should be pressed as little as possible otherwise the teeth of the comb will split at the points. They are shaped chiefly by means of rasps and scrapers of various forms, after having been roughed out by a hatchet or saw: the teeth are cut by a double saw fixed in a back, the two blades being set to different depths so that the first cuts the tooth only half way down, and is followed by the other which cuts to the full depth; the teeth are then finished and pointed by triangular rasps. If a comb or other article is too large to be made out of one plate of horn, two or more may be joined together by the dexterous application of a degree of heat sufficient to melt but not decompose the horn, assisted by a due degree of pressure; and when well managed, the place of juncture cannot be perceived. The Chinese are remarkably skilful in this kind of work, as may be seen in the large globular lantern in the Museum at the East India House, about four feet in diameter, composed entirely of small plates of coloured and painted horn. Horn combs are made in London in York and in many other English towns; but the chief manufactory of them is at Kenilworth, in Warwickshire.

If a work in horn, such as one of the large combs worn by women, is required to be of a curved or wavy figure, it is finished flat, and is then put into boiling water till it becomes soft, and is immediately transferred to a die of hard wood in

which it is cautiously pressed, and remains there till cold.*

Horn combs ornamented with open work are not made in this country, because the expense of cutting them would be more than the price of the article would repay; but great numbers of them are imported from France. These however are not cut but pressed in steel dies made in London for the French manufacturers; and from an examination of these combs it is evident that the material must have been in a soft state approaching to fusion, when put into the die. On referring to French authorities, I find it stated that horn steeped for a week in a liquor the active ingredient of which is caustic fixed alkali, becomes so soft that it may easily be moulded into any required shape. Horn shavings subjected to the same process become semi-gelatinous, and may be pressed in a mould into the form of snuff-boxes and other articles. Horn however so treated becomes hard and very brittle, probably in consequence of its laminated texture being obliterated by the joint action of the alkali and strong pressure.

Drinking cups of horn are thus made. The horn being sawn to the required length is scalded and roasted over the fire as already described; but instead of being slit and opened, is placed while hot in a conical mould of wood; a corresponding plug of wood

* Combs among the Romans were made of box-wood.

Quid faciet nullos hic inventura Capillos
Multifido *Buxus* quæ tibi dente datur.

MART. *Epig.* xiv. 25.

is then driven hard in to bring the horn to shape. Here it remains till cold, and is then taken out and fixed by the large end on the mandril of a lathe where it is turned and polished both inside and outside, and a groove, or chime as the coopers call it, is cut by a gage-tool within the small end for receiving the bottom. The horn is then taken off the lathe and laid before the fire, where it expands and becomes somewhat flexible; a round flat piece of horn, of the proper size (cut out of a plate by means of a kind of crown-saw) is dropped in and forced down till it reaches the chime, and becomes perfectly fixed in this situation and water-tight by the subsequent contraction of the horn as it cools. Captain Bagnold informs me that he has seen in South America a nest of such cups turned to a thickness not exceeding that of a card and accurately fitting into each other, the outer one holding about a pint and the inner one little more than an ounce.

Horn is easily dyed by boiling it in infusions of various colouring ingredients, as we see in the horn lanterns made in China. In Europe it is chiefly coloured of a rich red-brown to imitate tortoiseshell, for combs and inlaid work. The usual mode of effecting this is to mix together pearlash quicklime and litharge with a sufficient quantity of water and a little pounded dragon's-blood, and boil them together for half an hour. The compound is then to be applied hot on the parts that are required to be coloured, and is to remain on the surface till the colour has struck: on those parts where a deeper tinge is re-

quired, the composition is to be applied a second time. For a blacker brown omit the dragon's-blood. This process is nearly the same as that employed for giving a brown or black colour to white hair; and depends on the combination of the sulphur, which is an essential ingredient in albumen, with the lead dissolved in the alkali and thus introduced into the substance of the horn.

In very early times bows were made of horn. Homer describes the bow of Pandarus (*Il.* iv.) as made of the two horns of a wild goat united base to base, reduced into proper form and polished and then tipped with gold. The bow of Ulysses was also of the same material (*Odyss.* xxi). The long-bow of the English archers was, I believe, entirely of wood; but in the East, even at the present day, bows are made entirely or in part of horn. To the kindness of Colonel Taylor I am indebted for the opportunity of exhibiting to you a Chinese bow made partly of wood and partly of buffalo's horn. The same gentleman likewise informs me, that he has bought in Calcutta pretty good bows made entirely of buffaloes' horn; but the best Indian bows, those namely of Lahore, are made of horn combined with wood and strapped round with sinew. Horn lanterns were also used by the ancients; for we find one mentioned in the *Amphitryo* of Plautus* and in an epigram of Martial.†

* Quo ambulas tu, qui Vulcanum in cornu conclusum geris?
Amphitry. Act i. 1. 185.

† Dux Laterna viæ clausis feror aurea flammis,
Et tuta est gremio parva lucerna meo.—MART. *Epig.* xiv. 61.

Pliny* also speaks of horn-lanterns, and says that various other ornamental articles were made of dyed and painted horn.

Horn was also used as we now employ glass in windows; for which however it is not very well adapted, as plates thin enough to be transparent would soon warp and be corroded by exposure to the weather.†

Horns are also of very ancient use as musical instruments: the true bugle-horn was made of the horn of the urus or wild bull, tipped with silver and slung in a chain of the same material.

Another use to which horn has been applied is as a material for defence. I remember to have seen, several years ago, a complete suit of scale-armour made of horn. It was said to have come from Arabia, and seemed very capable of turning the edge of a sword or a pistol-bullet.

I now proceed to mention some particulars respecting TORTOISESHELL.

The animal which produces this beautiful substance is a marine tortoise, called the *Testudo imbricata,* or

* Cornua apud nos in laminas secta translucent, atque etiam lumen inclusum latius fundunt; multasq. alias ad delicias conferuntur, nunc tincta, nunc sublita, nunc quæ cestrotæ picturæ genere dicuntur.—*Hist. Nat.* xi. 45.

† Corneum specular.—TERTULL. *de Animâ,* liii.

hawksbill turtle. Its Latin name is derived from the mode in which the scales on its back are placed, overlapping one another like the tiles on the roof of a house. In this circumstance it seems to differ from almost all others of its genus; the scales of other tortoises, both those which are land animals and those which inhabit water either salt or fresh, generally adhering to each other by their edges like a piece of inlaid work. These plates, in all the tortoises, cover the bony arch of the back formed by the ribs and spine united into one immovable convexity by flat bones stretching from rib to rib and uniting insensibly with the spine.

The hawksbill turtle is a native of the torrid zone, and is found in the Indian seas as far as New Zealand, on the coast of Africa, on that of New Granada in South America, and in many parts of the West Indies especially on the Mosquito shore and the promontory of Yucatan. Its usual length is about three feet; but specimens have sometimes been found five feet long and weighing five or six hundred pounds.

The number of plates produced by each tortoise is thirteen; namely five along the back and a row of four others on each side: there are also twenty-five much smaller ones forming the margin of the shell. The size and thickness of the plates depend on the magnitude and age of the animal, a fresh layer being produced every year; and at the margin of the large plates may be seen distinctly the edges of the layers as they thin off in succession. Sometimes however large plates are met with, so thin as to consist appa-

rently of only a single layer. The cause of this anomaly I do not know; but some of the dealers in this article have an opinion that these thin plates are the produce of full-grown tortoises that have been stripped of their plates the year before, either purposely or by accident.

The plates are separated by placing the arch of the shell (all the other parts having been removed) over a fire, which soon causes them to start from the bone by the help of a slender knife. The price of rough tortoiseshell depends on its quality, that is on its thickness and the vividness and distinctness of the colours. The present price for fine shell is about three guineas a pound. Not unfrequently the plates are considerably injured by barnacles limpets and other shell-fish, which fix themselves on the animal while alive, and prevent the growth of the tortoiseshell on that part which they occupy. Sometimes one or more of the plates will be of a plain yellow colour; and such are in great request among the Spanish ladies, who will give twelve or fourteen dollars for a comb of plain tortoiseshell, while a similar one of the mottled kind will not sell for more than six dollars. The belly-plates of the tortoise are also yellow, and sometimes clear enough to be made use of.

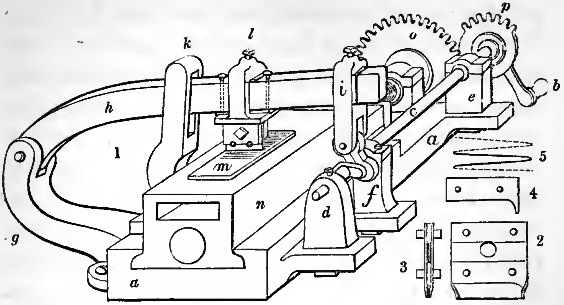
The general mode of manufacturing tortoiseshell is the same as I have already described when treating of horn. It is softened by boiling in water; but mere water takes away much of the colour: an addition of common salt prevents this injury; but if too strong a

brine is used the shell will be very brittle. Two or more pieces of tortoiseshell may be joined by laying their scraped or thinned edges together, then placing them between two thin boards and inserting the whole in the chops of a screw-press. The press is put for some hours into boiling water and is tightened from time to time, and thus at length a perfect junction is obtained at a heat so low as not to injure either the colour or texture. If a dry heat is applied by means of a hot iron it is generally in excess, in which case the colours are much deepened so as to become almost black, as is the case with moulded snuff-boxes; for tortoiseshell being less fusible than horn, cannot be made soft enough to be moulded without some injury to the colour. Accordingly the manufacturers, at least in England, never attempt to produce tortoiseshell combs with ornamental open work by means of dies but in the following manner.

A paper being pasted over the tortoiseshell, the pattern is drawn on the paper and is then cut out by means of drills and fine saws: the paper is then removed by steeping in water and the surface of the pattern is finished by the graver.

In making small side-combs it is found worth while, in order to save a costly material, to employ a machine the most convenient form of which, invented by Mr. W. Rogers, is represented in the subjoined figure copied from the 49th volume of the Transactions of the Society of Arts &c.

a a is a plate which supports the other parts and is secured by screws to any suitable bench. *b* is a winch

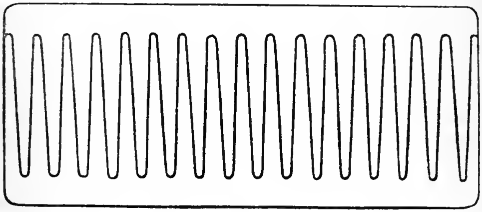


or handle attached to the axle *c*. *d e* are two upright pieces in which the two ends of the axle work and *f* is another upright between which and *d* the crank of the axle is situated. *g* is a piece projecting from the bottom plate *a* on which is hinged the bar *h*; at the end of this bar is the collar *i* secured by a screw, and connected by means of a link with the cranked part of the axle. It is evident therefore that when the axle is turned round by means of its winch an alternate up and down motion will be given to the bar *h*, *k* is a loop in which the bar works and which prevents it from swerving to either side, *l* is the cutter and *m* is a piece of tortoiseshell out of which two parted combs are to be made.

The cutter figs. 2 and 3 consists of two sharp blades of steel bent outwards a little at one end, between which are placed wedged shaped pieces so as to cause the blades to diverge from each other at the bent end by any required distance; at the other end the blades come nearly but not quite in contact, and this space

is filled up by the insertion of the piece fig. 4, the sharp tooth of which is so adjusted as to be even with the edge of the blades. When therefore this compound cutter is pressed down on the surface of the tortoiseshell a tooth, such as shown in fig. 5, will be formed. But in order to make a succession of such teeth two conditions are necessary; one, that the piece of tortoiseshell shall have a progressive motion, and the other that this motion shall be suspended while the cutter is making its blow. Both these conditions are effected in the following manner. *n* is the bed on which the tortoiseshell *m* is laid, in front of which is seen a rectangular opening into which a heated bar is put; the bar lies directly below the tortoiseshell and by keeping it warm preserves it from splitting by the action of the cutter. The bed slides in a dovetail groove made in the plate *a* and has a hollow screw in that end of it which is adjacent to the toothed wheel *o*. From the centre of this wheel projects a solid screw which turns in the hollow one and consequently moves the bed in one direction or the other according as the toothed wheel is turned one way or the other. The wheel *o* receives its motion from the wheel *p*, which being placed on the axle *c* is turned, together with it, by the winch *b*. But the wheel *p* has teeth only on part of its circumference, and therefore while this is in continued motion will give an alternation of motion and rest to the wheel *o*, and consequently to the piece of tortoiseshell *m*. While this latter is at rest the cutter

makes its stroke, and while the cutter is rising to make another stroke the piece of tortoiseshell moves through a space equal to the interval between one tooth of the comb and the next. When these actions have been repeated along the whole length of the tortoiseshell the subjoined figure (which is shown full size or nearly so) is produced, and then a slight pull will part the two pieces each of which is a separate comb.



Such combs are called *parted*, the saw not being used on them; and are often made of fine stained horn instead of tortoiseshell. Tortoiseshell is also used for inlaying tables, cabinets, and other ornamental articles, a metallic foil being placed below it to give lustre and colour. This employment of it appears to be coming at present considerably into fashion.

Among the Romans of the Augustan age, this taste was not so much a fashion as a fury. The frames of the couches on which they reclined at table were covered with the largest and most beautiful plates

that could be procured of tortoiseshell ; * and it was employed for various other similar purposes : but I am not aware that it was ever used by them as a material for combs. It was brought by Indian and Arabian traders from the islands in the Indian Sea to Oponé a port a little to the south of the extreme eastern promontory of Africa (the present cape Guardafui), and to Adulis† in Abyssinia, together with ivory, rhinoceroses' horns, and hippopotamuses' hides. Here it was purchased by Egyptian merchants, was transmitted to Alexandria, and thence passed to Rome and the other great cities of the empire. For modern uses, thick tortoiseshell is more valuable in proportion than thin ; but among the Romans, where it was used only for inlaying, veneers were cut out of it. This art was the invention of one Corvilius Pollio, a man, as Pliny ‡ says, of singular sagacity in all things that ministered to prodigal luxury.

* Attonitus pro
Electro signisq. suis Phrygiâque columnâ
Atq. Ebore, et latâ Testudine.—Juven. xiv. 306.
Ut Testudineo tibi, Lentule, conopeo
Nobilis Euryalum myrmillonem exprimat infans.—*Ibid.* vi. 80.
Gemmantes primâ fulgent Testudine lecti.—Mart. xii. 66.
Et Testudineum mensus quater hexaclinon.—*Ibid.* ix. 60.
Varios—pulchrâ Testudine postes.—*Georg.* ii. 463.

† Opidum Aduliton—maximum hic emporium Trogloditarum, etiam Æthiopum. — Deferunt plurimum Ebur, Rhinocerotum cornua, Hippopotamorum coria, chelyon Testudinum. — Plin. *Hist. Nat.* vi. 34.

‡ Testudinum putamina secare in laminas, lectosque et repositoria his vestire, Corvilius Pollio instituit, prodigi et sagacis ad luxuriæ instrumenta ingenii.—Plin. *Hist. Nat.* ix. 13.

WHALEBONE, as I have already stated, may be considered as a kind of horn; which latter substance it resembles perfectly, both in its chemical and principal physical properties, and is particularly interesting as forming the transition from horn to hair.

It is the substitute for teeth in the Greenland whale, and in the black southern whale; but is not found in any of the cetaceous animals that have teeth.

The food of the Greenland whale is a small crustaceous animal not so large as a common shrimp; and the whalebone forms the apparatus by which this huge animal secures the minute prey that he lives on. From the roof of the mouth hang down on each side the tongue about three hundred blades of whalebone, all the blades on one side being parallel to each other, and at right angles to the jaw-bone. On account of the arched form of the roof of the mouth, the blades about the middle of the series are the longest, and they diminish gradually towards each end. The average length of the middle blades is about nine feet; but they have occurred of the length of fourteen or fifteen feet. These blades hang down in the mouth so that the hairy side shall be the innermost; the hairs forming a net or filter through which the water escapes, leaving the shrimps behind.

The surface of the blade is compact, and susceptible of a high polish by mere friction. Its texture is lamellar near the surface, so that it easily splits and divides: but the interior of the blade is of a looser texture than the rest, and is technically called the

grain, being composed of coarse, bristly hairs. The general colour of whalebone is a dusky greyish black, intermixed with thin strips or layers of a paler colour, which are often almost white—very rarely the entire flake is milk-white.

The preparation of the whalebone for use is very simple. It is boiled in water for several hours, by which it becomes soft enough to be cut up, while hot, in lengths of different dimensions according to the use to which it is to be applied; or, by means of a compound guarded knife, is cut into fibres for brushes, which are at present extensively used in stables for the first process in cleaning a horse. Whalebone that has been boiled and has become cold again, is harder and of a deeper colour than at first; but the jet-black whalebone has been dyed. The principal consumption of whalebone at present is for stretchers to umbrellas and parasols: it is also used, though not so much as formerly, in giving stiffness to women's stays. Whips are also made of platted whalebone, both black and white: the latter are very beautiful. White whalebone has also been made into ladies' bonnets, and likewise into artificial flowers, as its texture is well adapted to this purpose; and it will, by the usual dyeing processes, take very bright and durable colours.

VIII. THE ANTIQUARIAN HISTORY OF IRON.

To some it may appear that the special object of this evening's illustration, namely the antiquarian history of iron, is quite inconsistent with the generally practical nature of these meetings and of the views and objects of the Society of Arts; and certainly, if my intention were to take up the art of working iron such as it exists at the present day, there would be but small necessity for inquiring where and how it was wrought some centuries ago, and what were the uses to which it was at that time applied. The smelter the blacksmith the cutler pursue their respective arts without troubling themselves by inquiring into the obsolete practices of their predecessors, or with recording for the benefit of posterity the results of their own experience: they look upon their occupations only as ways of gaining money, and, this done, they are content. The spirit of curiosity and of inquiry is dead within them precisely on those subjects concerning which they know the most and with which they are the most familiarly acquainted, and

for that very reason. As soon as the exercise of their art becomes easy through habit, it degenerates into a mere routine; and even the most intelligent workmen have rarely any curiosity concerning matters which form their daily employment, beyond obtaining from a given quantity of labour a greater amount than usual of profit.

It was from a deep and exaggerated perception of this tendency in mechanical and handicraft occupations as usually carried on to contract the faculties of the mind, that the philosophers of old were induced to draw the broad line of distinction between liberal and illiberal arts, between those worthy of a free man and those that were consigned to the compelled labour of the slave. In so doing they acted unwisely; for, by raising an additional prejudice against the labouring part of society, they prevented even themselves from perceiving that the commonest and most mechanical occupations are allied by their principles to the highest and most abstract philosophy; and that it is only by the laborious collation of individual facts that we are able to construct those engines of philosophizing called theories, or to limit and modify the deductions from theory by the results of actual experiment. To this contemptuous ignorance of theirs concerning the practical arts of common life it is owing, that so little has been handed down to modern times of those ingenious arts and occupations which busied the swarming populations of Sidon of Tyre of Miletus of Samos of Athens of Syracuse of Tarentum of Alexandria and of Carthage, once independent and

rival queens of the Mediterranean sea, now mostly in dust and ashes, and of some of which even the ruins have almost disappeared. Fragments however of these forgotten arts may yet be recovered by a diligent perusal of ancient writers, which, when collected and properly arranged and commented on by the more accurate and extended knowledge of the present day, may illustrate the domestic the civil the commercial and the military histories of the ancient world. It is the hope of bringing a small contribution of this kind which has induced me to undertake the reading necessary to collect the materials for this evening's illustration, and if by so doing I shall occupy you for the accustômed time neither disagreeably nor uselessly, and shall awaken even in a single mind the echoes of ancient literature scarcely audible amidst the clamour and agony of competition by which the present times are characterised, my end will be answered, my reward will have been attained.

The inquiry on which I am now about to enter may be divided into three sections: the first relating to the knowledge of iron possessed by the Hebrews and by the nations with whom they were in the habits of intercourse; all the materials for which must be derived from Jewish records.

The second section will treat of the knowledge and uses of iron among the Greeks, and the third will carry on the same investigation as relates to the Romans and to those northern tribes, chiefly barbarous, with which we are acquainted through the medium of the Latin writers.

I. *Iron among the Hebrews.*

The cultivation of the earth, the domestication of sheep, goats and cattle, the invention of musical instruments, the discovery of metals, particularly iron* and brass and of the arts by which they are adapted to human use, are recorded as the four great conquests made by man over nature prior to the flood. We may therefore conclude that, even in the time of Moses, the discovery of iron and of brass, meaning by this latter word not modern brass but copper with all its common alloys, ascended into the profoundest night of antiquity.

In the books of the Mosaic law, Egypt, in reference to the severe oppression suffered there by the Israelites, is called the Iron furnace:† but the summary of the law in which this passage is to be found was given just before the invasion of Palestine; and as the Israelites had grown up to be a nation in Egypt, and since their departure from that country had been wandering in the desert, it is manifest that the only opportunity which they had possessed of knowing even the meaning of the term "iron furnace" must have been during their residence in Egypt. We may therefore, I think, fairly conclude that iron was at this time worked in Egypt; and the deliverance from the iron furnace would from the lips of Moses have an

* Tubal-Cain, an instructor of every artificer in brass and iron.—*Genes.* iv. 22.

† The Lord hath brought you forth out of the iron furnace, even out of Egypt.—*Deut.* iv. 20.

emphatic application if, as is not improbable, one of the forms of slavery which had been employed to coerce the rapid multiplication of his countrymen, had been incessant toil in the Egyptian mines; a toil which the Greek Diodorus, several centuries afterwards, represents as the most intolerable of all tyrannies.

In the same book Palestine is described by all the circumstances that rendered it a desirable residence; its springs and streams of running waters, its rich agricultural produce, and as "a land whose stones are iron, and out of whose hills thou mayest dig brass." *Deut.* viii. 9. I am not aware of any passage which mentions in direct terms the working of iron mines either by the Jews or by any other of the people who dwelt in Palestine, but there are several notices dispersed through the four books of the Mosaic law which show that iron was a metal well known and in general use. The bedstead of Og the gigantic king of Bashan was of iron. *Deut.* iii. 11. Iron tools were used in hewing or squaring stones. *Deut.* xxvii. 5. Saws harrows and heads of axes* were made of iron. I have not been able to find any direct testimony respecting the material of which swords and other offensive weapons used in war were made at this time, but I am inclined to think that they likewise must have been of iron, both because no other material is mentioned, and because it is stated in the Mosaic law that "if any one smite another with an instrument of *iron* so that he die, he is a murderer."

* Deut. xix. 5. 2 Sam. xii. 31.

At this period too the Philistines are represented as having chariots of iron, *Judg.* i. 19; and, not long after, Jaban king of Canaan reduced the Israelites to subjection for twenty years by means of his 900 chariots of iron. *Judg.* iv. 3. These chariots were probably war-carts with perhaps scythes attached to the axles of their wheels, such as were in use by the sovereigns of Assyria and Mesopotamia, and whose charge on level ground could not fail of being extremely formidable to infantry, of which the Israelitish armies before the appointment of kings appear entirely to have consisted.

In the time of David defensive armour and the boss of the shield were of bronze, spears were pointed with iron; at least Goliath is represented as thus armed; and in the splendid επινικιον or hymn of victory composed by David after the reduction of all his enemies, mention is made of a *bow of steel;** but, as this expression in the passage alluded to has a metaphorical sense, it can hardly be cited as authority for a fact of so much importance.

Previous to the Babylonian conquest the Jews were acquainted with two kinds of iron; namely that in common use and a much superior sort known by the name of Northern iron.† At first sight this passage may seem to allude to the celebrated iron or steel made by the Chalybes, a people who lived on the southern shore of the Black Sea and nearly due north of Palestine, concerning whom I shall have more to

* 2 Sam. xxii. 35.

† Shall iron break the Northern iron?—*Jerem.* xv. 12.

say in the second section of this inquiry. But on a more careful consideration I am inclined to think that this is not the case, but that we are to look to the countries *east* of Babylonia for the place where this steel was prepared. In the geography of Jeremiah and of Isaiah and of the later Jewish prophets the word north is used with great latitude and not unfrequently means the east. In Isaiah we have the word north used expressly as synonymous with "the rising of the sun:"* the impending invasion of the king of Babylon is called danger from the north,† and the Jews when after the captivity they were restored to their own country are said to have been brought back from the north. The destruction of Babylon itself by the Medes and Persians, nations inhabiting due east of that city, is described by the expression "a nation from the north shall make her desolate." ‡ The eastern locality of this so called northern iron will be rendered more apparent by the next and last passage that I shall cite as relating to this first section of my subject.

In the book of Ezekiel § is a section called the "Lamentation for Tyre" containing an enumeration of the different countries with which this great emporium carried on intercourse, and of the commodities

* I will raise up one from the north and he shall come, from the rising of the sun he shall invoke my name.—*Is.* xli. 25.

† Out of the north an evil shall break forth——I will call all the families of the kingdoms of the north.—*Jer.* i. 14.

‡ Jer. l. 3. 9. 41; li. 11.

§ Ezek. xxvii. 12. 19.

which she imported from each of them. In this list are two passages extremely interesting with relation to the commercial history of iron. The first of these is as follows, "Tarshish was thy merchant by reason of the multitude of all riches; with silver, iron, tin and lead they traded in thy fairs." All modern critics are agreed that Spain is the country designated in the Jewish writings by the name of Tarshish, of which name some indications are perhaps to be traced in the romanized appellations of three maritime towns, Tartessus at the mouth of the Guadalquiver near Cadix, and Dertosa and Tarraco, the former at the mouth of the Ebro and the latter a little way to the east of it. After the destruction of Tyre, her colony Carthage succeeded to the possession of the rich trading stations of Tarshish, from whence after a long struggle they were expelled by the Romans. To the two latter of these nations, as to Tyre herself, Spain proved an inexhaustible source of mineral wealth, the same four metals, viz. silver tin iron and lead continued to be poured forth in abundance as, with the exception of silver, they still are from the same country at the present day. It was probably in part from Celtiberia, and in part from Catalonia a district between the lower Ebro and the Pyrenees celebrated in all times for its iron, that this metal was imported to the Tyrian markets: and I may observe here, by the by, that the old Catalonian method of obtaining bar iron directly from the ore, without going through the usual process of smelting, and which even now is

hardly obsolete in that province, is, from its character of rude simplicity, not unlikely to be the very process made use of for the supply of the Tyrian market 2300 years ago.

The last of the two passages in this description which I am desirous of calling to your notice is the following: "Dan also and Javan going to and fro occupied in thy fairs, *bright iron* cassia and calamus were in thy market." Here I would remark that the epithet bright applied to this iron, seems to distinguish it from common iron: that the same merchants who brought this also brought cassia and calamus, two aromatic substances that probably were obtained from the countries to the east of Persia whence they were brought by land carriage in caravans "going to and fro." If this "bright iron" were the common malleable form of this metal it could never have entered into competition with the iron of Tarshish conveyed by water carriage; we may therefore I think, without any great chance of error regard it as the "northern iron or steel" already mentioned, susceptible of a bright polish and perhaps not differing from the *wootz* of modern India.

II. *Iron among the Greeks.*

The concurrent opinion of all Greek writers who have mentioned the subject attributes an earlier date to the invention and use of bronze than of iron. Thus Hesiod, either the first or at least the second in antiquity of the Greek writers, speaking of the four ages of the

human race, after describing the golden and the silver age thus characterizes the third or brazen age—

> Brazen was their armour, brazen their houses,
> In brass they worked, for black iron was not as yet.*

Of the age in which he himself lived he says,

> —— the present is the iron age.†

A still more remarkable proof of this fact exists in the word used by the Greeks to express the occupation of a smith being, when translated into English, that of "a worker in bronze;" the smith's forge or hearth is called "the brazier's hearth" ‡ even where it is expressly stated that iron was the substance on which the workman was employed.§ This use of the word, having been fixed in the earliest times by the fathers of Greek literature Hesiod and Homer, continued century after century down to the commencement of the Christian era. But if the term "worker in bronze" was thus applied indifferently to the worker in iron also, it is evident that there must have been, if not a perfect identity, yet at least a considerable resemblance in the mode of working the two metals. The tools of the Greek brazier or smith are always represented as bellows, an anvil and

* ——χαλκεα μεν τευχεα, χαλκεοι δε τε οικοι,
Χαλκῳ δ' εργαζοντο, μελας δ' ουκ εσκε σιδηρος.
Opera et Dies, 149.

† Νυν γαρ δη γενος εστι σιδηρεον.—174.

‡ χαλκειον θωκον.—491.

§ So also Herodotus. Lichas going into Tegea entered a smith's forge (χαλκηιον) and looked on while he was hammering the iron (σιδηρον εξελαυνομενον).

hammers, and water in which to quench the heated metal. Bronze is an alloy, a compound of copper and tin, but there is no evidence that the Greek smith composed his bronze by melting together the two ingredients; and the probability is that ingots of bronze, ready made and of sizes adapted to different kinds of work, were brought to all the ports of the Greek seas by Phœnician, that is, Sidonian or Tyrian merchants: for we know from many passages in Homer and from the tradition of Greek events before the Trojan war, that even in the earliest times Phœnician galleys frequented the Greek seas for the purpose of trading and of kidnapping slaves. As a farther confirmation of this opinion it may be stated that the only tin mines ever known to be worked in Europe are those of Spain of Cornwall and of Bohemia. The latter country, covered by forests, was wholly unknown as a metalliferous district till comparatively speaking, modern times. The Phœnicians were in possession of the Spanish mines, and Cornwall (insulæ cassiterides) if known at all was only visited by the same enterprizing mariners.

The subjects of the poems attributed to Hesiod are not of a kind to admit much notice of the metals. We find however that the nails of the hand were pared with *bright iron** and, as in a passage already referred to, the same writer speaks of *black iron,* we may infer that bright iron or white adamant,† an expression also used in this very poem, is to be under-

* *αιθωνι σιδηρῳ.*—741.

† *γενος πολιου αδαμαντος.*—*Theog.* 161.

stood of steel, and that it is the same substance as the "bright iron" of Ezekiel previously described; indeed a knife of mere hammered iron would not be capable of cutting the horny substance of the finger-nail. Another passage occurs in a different poem of the same writer in the form of a simile describing the reduction of iron ore. "As," says he, "hardest iron* in the mountain dales subdued by burning fire melts in the divine land under the hands of Vulcan."

Now, a simile is for the purpose of exemplification; and therefore we may reasonably infer that works for smelting iron had by this time been erected in some of the woody vales of Mount Helicon, where the poet is said to have passed at least the years of his early youth as a shepherd.

In the same poem we find the expression "Death, of iron heart" † and "mind of adamant," which clearly show a perfect and familiar acquaintance on the part both of the poet and his audience with the obvious properties of iron and steel — a circumstance which seems to assign a later era to Hesiod than to Homer, or to justify the suspicions of critics that this particular poem has been largely interpolated.

The two great poems of Homer, the Iliad and Odyssey, abound in notices of the metals, of which I shall select only a few for the purpose of showing the respective uses to which iron and bronze were put at the time when those poems were written. I do not say at the time of the Trojan war, for we know from

* σιδηρος ὅ περ κρατερωτατος.—865.

† σιδηρεη κραδιη.—746. αδαμαντος θυμον.—239.

innumerable examples the carelessness of poets with regard to what is called costume; and that their illustrations and casual notices are drawn from the objects and manners with which they are themselves familiar, rather than from those that best harmonise with the time and place where their scenes are laid. Homer then, represents defensive body armour for real service as made of bronze, the shield was of hide with an external plate or at least a boss of bronze. The sword and the point of the spear were also of the same material: the sword of Achilles made by the god Vulcan, and therefore of most perfect workmanship and of the most effective material, is of bronze with a silver handle: indeed the word "bronze" is used by itself as signifying offensive arms of any kind, so that where Pope in his translation of the Iliad employs, agreeably to the usage of his own day, the word steel as synonymous with sword or spear, Homer uses the word bronze.* At the same time however iron and at least common steel were perfectly well known and in common use for many purposes, so that it is a matter of wonder why it did not almost supersede the use of bronze. One of Homer's heroes encouraging his men to attack the enemy, says of them, "Their flesh is neither stone nor iron (σιδηρος) to endure strokes given with the cutting edge of bronze (χαλκου)."† Why then it may be asked was not defensive armour made of iron? The answer may be that, if this change were made, cutting wea-

* *ωρνυτο χαλκῳ*—he rushed on with his weapon.—*Il.* iii. 349.

† *Il.* iv. 510.

pons would also be made of the same material, and thus the means of attack and defence would be brought to the same relative proportion as when bronze was used for both.

Iron was used for felling axes,* for double-headed axes for slaughtering cattle, for shipwrights' tools, for the axles of chariots,† for pointing ploughs, for sheep-hooks and agricultural implements.‡ For cargoes of wine supplied to the camp before Troy, were given in exchange bronze and iron.§ Among the spoils gained by Achilles in sacking the towns of the Trojan allies were gold, ruddy bronze and white iron.||

The last passage that I shall quote from this writer is a simile in the Odyssey as follows:—"As some smith" (worker in bronze is the original word) "plunges into cold water a loudly hissing great hatchet or adze tempering it, for hence is the strength of iron."¶ Few words are required to show that two things are clearly proved by these lines, first that the art of tempering steel was practised just as it is at the present day for common cutting tools, and that the worker in iron or steel was called a brazier.

It is rather remarkable that no notice exists in Homer of the locality of any iron mines or of the commercial history of this metal.

* *Il.* iv. 485. † *Il.* v. 723. ‡ *Il.* xxiii. 826.
§ *Il.* vii. 473. || *Il.* ix. 365.

¶ Ως δ' οτ' ανηρ χαλκευς πελεκυν μεγαν ηε σκεπαρνον
Ειν υδατι ψυχρῳ βαπτει μεγαλα ιαχοντα
Φαρμασσων (το γαρ αυτε σιδηρου τε κρατος εστιν).
Odyss. ix. 391.

After a long interval, during which no Greek writer existed whose works have come down to us, we arrive at the time of the Persian invasion of Greece by Darius and his successor Xerxes, contemporary with whom is Herodotus; from passages in whose history we may infer that the use of bronze for arms was already discontinued in Greece. Speaking of the Massagetæ he says "their spears, arrow-heads and axes are made of bronze (χαλκω), for, though in their country they have plenty of gold and bronze, they have neither silver nor iron." The same author in his first book, mentioning the presents sent to the temple at Delphi by Alyattes king of Lydia, father of Crœsus, particularizes a patera (ὑποκρητηρίδιον) of inlayed iron the work of Glaucus of Chios who invented this method of working iron. Æschylus, the earliest of the Greek tragedians and who fought at Marathon against the Persians, was born about 460 years B.C. In two of his plays, the Prometheus and the Seven Chiefs against Thebes, are the first notice of the Chalybes, a people inhabiting the country on the S.E. of the Black sea. About or before this time their steel, of excellent quality, seems to have been largely imported into Greece and to have caused the disuse of bronze for swords and other offensive arms. In the imperfect geography of the Greeks all the countries on the shores of the Black sea and thence indefinitely northward and eastward were confounded together under the general term Scythia, hence Chalybian and Scythian are used by Æschylus indifferently. He speaks

of the Chalybes as workers in iron,* of Scythia as a land the mother of iron :† and of the sword as "sharp iron the bitter appeaser of strife, the Pontic stranger born in fire,"‡ and also as "the Chalybian stranger come out of Scythia."§ From this time dates the use of the word Chalybs in Greek as signifying steel of best quality, whence it passed unchanged into the Latin language, and may at the present day be recognized in our own in the expression chalybeate waters, chalybeate medicines, &c. in consequence of some commercial transactions which took place more than twenty-three centuries ago between Greece and a country on the Black sea.

Aristotle describes the iron of the Chalybes|| as so much whiter than other kinds that it might almost be mistaken for silver. The method of manufacturing steel, probably by Greek workmen, he describes as follows: —"Steel¶ (*στομωμα*) is made by melting wrought iron (*ειργαζομενος σιδηρος*) and then letting it become solid; for by this means the scoriæ are purged away. By repeating this process several times the iron becomes steel: this method however is not often practised on account of the great loss of weight which

* *σιδηροτεκτονες Χαλυβες.*—*Prom.* 715.

† *σιδηρομητερα αιαν.*—*Prom.* 301.

‡ *πικρος λυτηρ νεικεων, ὁ ποντιος*
Ξεινος εκ πυρος συθεις
Θηκτος σιδαρος.—*Septem.* 949.

§ *Ξενος . . . . . .*
Χαλυβος σκυθων αποικος.—*Septem.* 733.

|| De mirab. Auscult.

¶ Aristot. Meteor. ch. vi.

the iron undergoes, but the iron becomes the better the less impurity it contains." Hence it is evident that Aristotle regarded steel only as the purest state of iron.

Having thus lightly sketched, from the most authentic accounts that I have been able to meet with, the history of iron among the Greeks till it seems pretty generally to have superseded the use of bronze for cutting instruments, I proceed to the third division of this inquiry, namely—

III. *Iron among the Romans.*

It does not appear that bronze was ever used by the Romans for offensive warlike weapons or for cutting instruments of any kind. Pliny* indeed says that in the treaty which Porsenna imposed on the Romans after the expulsion of the Tarquins, it was a condition that they should not make use of iron except in agriculture. If there is any truth in this tradition it shows that the Romans had previously been in the habit of using military weapons of iron, and the same reason which originally induced them to employ this metal, would no doubt persuade them to resume its use as soon as they felt themselves strong enough so to do. Possibly, the Etrurians, of whom Porsenna was king, might use bronze weapons at this time, and might wish to reduce the Romans to the same level with themselves in this respect. The earliest historian about the Roman affairs is the Greek Polybius a personal friend of Scipio Africanus. In the fragments

* Nat. Hist. xxxiv. 14.

of his valuable history (for fragments only have come down to modern times) are some interesting notices respecting the military use of iron. The helmet of the Roman soldiers was of bronze, and many used a breast-plate of the same, but the shield had a boss of iron and an outer border of the same: the sword was a strong cut and thrust blade of Spanish steel; the spear likewise was pointed with iron.*

With regard to the Spanish iron mines Pliny informs us that in Cantabria near the sea-shore there is an entire mountain of iron ore. But the chief seats of the manufacture of iron and steel while the Romans possessed the country were in Celtiberia which included part of the present provinces of New Castille and Aragon. The town of Bilbilis appears to have been in the centre of the forges, and the little river Salo which falls into the Ebro was celebrated for giving a high temper to steel on account of the coldness of its waters. Martial † the epigrammatist was a native of this country and describes the town of Platea as noisy with iron-works, and extols the steel of Bilbilis as superior to that of the Chalybes or of Noricum the present Styria; and he recommends to

* Polyb. vi. 21.

† Pugio quem curvis signat brevis orbita venis,
Stridentem gelidis hunc Salo tinxit aquis.—xiv. 33.

Sævo Bilbilim optimam metallo
Quæ vincit Chalybasque Noricosque,
Et ferro Plateam suo sonantem,
Quem, fluctu tenui sed inquieto,
Armorum Salo temperator ambit.—iv. 55.

his friend cold bathing in the Salo which cannot fail to constringe his relaxed body since it hardens even iron.* Diodorus, a Greek, who lived in the times of Julius Cæsar and Augustus, and wrote a general history, describes the Celtiberians as armed with two-edged swords and daggers made of exquisite iron which they use in close fight. They bury plates of iron, says he, in the ground till the weaker parts are consumed by rust. Of the remaining iron they make swords strong enough to cleave a shield or helmet or to cut through a bone.†

Another place where much iron was made is the Island of Elba, celebrated even at present for the richness and abundance of its iron ore. According to Aristotle‡ the earliest mines wrought there were of copper, but these failing, the miners turned their attention to the iron ores. Diodorus§ says that the ore being first broken into small pieces is melted in an intense fire and then made into masses like large sponges, and in this half prepared state is exported to Dichæarchia and other places where by skilful workmen (*τεχνιτων χαλκεων*) it is made into axe-heads choppers and similar articles.

Pliny in his Natural History|| gives rather a full account of iron, from which I shall select such particulars as I have not yet mentioned, and with this I shall conclude the Roman history of iron.

* —— remissum corpus adstringas brevi
Salone, qui ferrum gelat.—i. 50.

† 215. ‡ Mirab. Auscult.

§ 204. || xxxiv. 39.

He observes that there are different qualities of iron; some being soft like lead and very tough, such iron is used for wheels and nails, some on the other hand is hard like bronze but brittle. At a red heat iron is scarcely malleable but completely so at a white heat.

He reckons Seric iron (which comes from the remote east) the best of all; the Seres send it together with their cloths and furs.* Next in goodness is the Parthian iron, and these are distinguished from all others in being of pure steel without any soft parts in them. Of nearly equal quality with the Parthian is the iron of Noricum (Styria).

Small articles of steel require to be tempered in oil for if thrown into cold water they would become brittle. Oil stones give a finer edge to steel than water stones.

The magnet stone is found in Cantabria. Iron receives from this stone and retains for a long time the property of attracting other iron (see also in Lucretius vi. 1000 an account of the magnet). The architect Dinochares was employed by Ptolemy to roof a temple at Alexandria with magnet, by means of which an iron image of his sister Arsinoe might remain perpetually suspended; but both Ptolemy and the architect died before the work was completed. Here we detect the origin of the vulgar fable about Mahomet's coffin suspended between two magnets. Pliny likewise mentions meteoric iron of the form of sponges, as having fallen in

* Indian iron (σιδηρος Ινδικος) is mentioned in the Periplus of the Erythræan sea among the articles sent from Alexandria to Adulis in Abyssinia.

Lucania the year before Crassus was defeated by the Parthians. "Ferro in Lucanis pluisse anno antequam M. Crassus a Parthis interemptus est—effigies spongiarum fere similis fuit." ii. 57.

I will not weary you by citing any more particulars about iron as known to and employed by the Romans: there are however two notices respecting the Gallic and German iron which are worth mentioning.

Polybius ii. 33, says that in the consulship of Publ. Furius and C. Flaminius (222 B. C.) an army of Insubrian Gauls entered the north of Italy, and were defeated by a Roman army chiefly from this circumstance; namely that their swords, like those of the Gauls in general, after having made one or two cutting blows, bent and could not be used again till they had been straightened by putting them under the foot.

It is evident that the iron of which these swords were made was of the kind at present called hot short, a defect which much of the iron now made in the southern departments of France is very liable to.

Tacitus * in his account of Germany after mentioning that it possesses no mines of the precious metals adds "Even of iron there is no superfluity, as may be inferred from the kind of weapons which they employ. They rarely use swords or the larger kind of lances, but arm themselves with spears or, to use their own word, *frames,* with a slender and short iron

* Germ. vi.

head.* Every one knows that at the present day there is no deficiency of iron in Germany, and the parsimonious use of it as mentioned by Tacitus only proves the rudeness of the tribes by which Germany was at that time occupied, or, it may be, the similarity of their iron to that of the Gauls.

The proximity of Gaul and Germany to the British islands and a natural curiosity respecting the ancient condition of the country in which we live, have induced me to search, but without success, for any notice in the classical writers respecting British iron, except a short notice in the commentaries of Julius Cæsar,† that iron is found, but in no great plenty, in the maritime districts of the island, meaning by this expression Kent and Sussex, those being the only parts of the coast with which he was acquainted.

For fear of exceeding unreasonably the time understood to be allowed on these occasions I have been obliged to omit many passages which I had selected as illustrating my subject: enough however has been brought to justify the following conclusions.

That from very early times the Egyptians and inhabitants of Syria were in the habit of using iron for cutting instruments and for other purposes, and that the iron mines of Spain have been worked at least ever since the times of the later Jewish kings of the race of David to the present day, first by the Tyrians,

* Ne ferrum quidem superest, sicut ex genere telorum colligitur. —Rarò gladiis aut majoribus lanceis utuntur; hastas, vel ipsorum vocabulo *frameas*, gerunt, angusto et brevi ferro.—*German.* vi.

† Bell. Gallic. v. 10.

next by the Carthaginians then by the Romans and lastly by the natives of the country. That a trade in iron or rather steel of the best quality, manufactured in the remote east and conveyed by land-carriage to Syria, existed at the same early period and continued at least as late as the first century of the Christian era. That the Greeks in the most early times though acquainted with the use of iron and perhaps of steel, did not employ it but bronze for offensive warlike weapons,—that after what are called the heroic ages of Greece the use of bronze, as above mentioned, was superseded by iron or by steel obtained from the Chalybes on the Black sea. That there is no evidence of the Romans, even in the earliest times, having used for offensive arms any material except iron—that the iron mines of Elba were worked at least as early as the time of Alexander of Macedon, and that afterwards the Romans obtained iron from Spain and from Styria.

But a discovery has been made in our own days and in those of our fathers which shows that in some parts of Italy, at least, the use of bronze for cutting instruments, for articles of furniture and for domestic use in general, was continued to a late period. I allude to the excavations made at Pompeii and Herculaneum, towns in the vicinity of Vesuvius and which were overwhelmed during the great eruption of that volcano in the year 59. From these mines of undoubted antiquities have been obtained all sorts of articles in stone and metal which were used in that day by the inhabitants of those towns. Some are of

iron but by far the greater number are of bronze. It is true that iron instruments may have been destroyed by rust during their long sepulture of near seventeen centuries, but, if such ever existed, the wonder and difficulty still remain how bronze and iron should ever be considered as equally applicable to the same uses. In all the Latin writers *ferrum*, iron, is the most common name for a sword, but the swords that have been found in these towns are of bronze, as also are the points of spears. Pollaxes and other sacrificing instruments have been found of the same material, even surgeons' instruments 40 in number, some with cutting edges, and all of bronze were discovered. The southern part of Italy was called magna Grecia (great Greece) in consequence of the numerous Greek colonies by which it had in early times been occupied; the use of the Greek language was common among their descendants, and no doubt many Greek customs and practices were retained by them; and it is possible that this very general use of bronze may have been derived from their remote Greek progenitors. There is no reason to suppose that the towns of Pompeii and Herculaneum were peculiar in this respect; and it might be maintained with at least great plausibility that the south of Italy even so late as the end of the first century presented in this very general use of bronze a faithful representation of the Homeric age.

In order to ascertain how far modern bronze is applicable to those purposes to which it is evident that the ancient bronze was applied I was induced to

make the following alloys. The materials which I employed were pure Swedish copper and the best grain tin. Mr. Devey the brass-founder, one of our members, was so good as to melt the materials and cast them under my own inspection, and to Mr. H. Wilkinson another of our members I am indebted for various trials and observations on the quality of the bronze as detailed in his very interesting letter, with which I shall conclude, only premising that the proportions of ingredients in the three varieties of bronze examined, are as follows:—

No. 1.	9 Copper 1 Tin	No. 2.	7 Copper 1 Tin	No. 3.	8 Copper 1 Tin

"Pall Mall, April 11, 1836.

"My dear Sir,

"The following are the results I have obtained from the specimens of bronze you left with me.

No. 1. $\left.\begin{matrix}9\text{ C.}\\1\text{ T.}\end{matrix}\right\}$ "Softest in the cast and hammered state, capable by hammering to the utmost it will endure without cracking, of bearing tolerably well an obtuse (cold chisel) edge; which will cut brass as the specimen I gave you proves. It requires to be frequently sharpened on a close-grained stone or with a burnisher. It can be cut by a chisel made of No. 2 or 3.

No. 2. $\left.\begin{matrix}7\text{ C.}\\1\text{ T.}\end{matrix}\right\}$ "Much harder than No. 1, when hammered will bear an edge sufficiently fine to make a quill-pen with difficulty and frequent sharpening. This alloy will make good

chisels for wood and punches for die-sinking, which improve by use, as the edge hardens; suitable for swords, knives, and, by proper management, springs.

No. 3. $\left.\begin{matrix}8\text{ C.}\\1\text{ T.}\end{matrix}\right\}$ "The hardest alloy of the three, but will not bear so much hammering as the other two. It appears to be about the hardness of soft cast-steel; but it is rather difficult to decide on hardness merely by fileing or cutting with a graver, when there are only slight shades of difference. It is almost as difficult to file as spring tempered steel, and requires new files when well hammered.

"*General Observations.*

"Not any of the specimens malleable at a red or white heat. They are most so when cold, and break under the hammer immediately while red hot.

"They appear to possess a remarkable property directly the reverse of steel. Making red hot and cooling very slowly *appears* to harden them, *it certainly does not soften*, but making red hot and dipping in water appears to soften. This, Dr. Faraday informs me, he found to be the case.

"Considerable elasticity is communicated to all by hammering, but No. 2 would make good springs in the absence of steel; and swords formed of No. 2 might perform wonders, not being opposed by any harder substance than themselves. The edge I have put on No. 2 is one likely to stand well, and is as sharp as many steel swords, particularly the celebrated Damascus ones, which often have as obtuse an

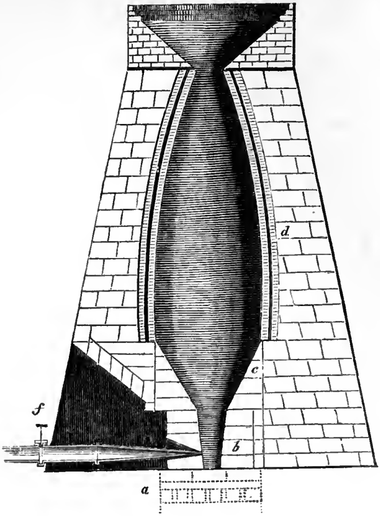
edge for cutting against or through iron. Homer's *forges* if properly translated might mean furnaces for melting, in order to cast into the most convenient forms, and the tempering would consist in making red hot, cooling slowly, and then hammering when cold as much as possible.

"I am, dear Sir,

"Very truly yours,

"HENRY WILKINSON."

"A. Aikin, Esq.
"Sec. Soc. Arts, &c."



IX. METALLURGICAL HISTORY OF IRON.—Part I.

CAST IRON.

I intend in the present Illustration to treat of cast iron, that kind especially which is obtained by means of coke, in contradistinction to that which is obtained by means of charcoal.

In the reduction of the ores of iron by the ancients, the metal was usually separated from the slag and other impurities by these latter being brought to a state of liquid fusion; but this was considered by them as only the first of a series of continuous processes the

final result of which was malleable iron. A few instances however are recorded of statues made by Greek artists by pouring melted iron into moulds. Of the particulars of this process we possess no details, and I am not aware that cast iron was ever applied by the Greeks or by any other people, till comparatively modern times, to any use except that just mentioned. The two principal passages relating to statues of cast iron are to be found in Pausanias and are sufficiently interesting to be quoted. The first of them is as follows:—"The temple of the Great Mother at Sparta is said to have been built by Theodorus the Samian, who first discovered the art of casting iron and of making statues of it." iii. 12. The second runs thus,—"At Delphi is dedicated a Hercules and hydra both of iron. To make statues of iron is most difficult and laborious; but this work of Tisagoras, whoever he was, is really admirable. In Pergamus are the heads of a lion and of a boar, both of iron." x. 18.

In the very curious and interesting work of George Agricola, *de Re Metallicâ,* written in 1550 we find an account of the method of obtaining iron from its ores, and of the preparation of steel, but not a word is mentioned of the use of iron for castings.

When cannon were first used in war they were made on the same principle as coopers construct their barrels; a number of iron bars fitting as close as possible to each other were arranged round a cylinder of wood and were then bound together by strong iron hoops, the wood being driven out there remained an iron

pipe which formed the barrel. This mode was superseded by casting the cannon of bronze; and at the end of Queen Elizabeth's reign, it is said, the English first attempted to substitute iron for bronze, being induced thereto by the greater cheapness of the latter material, by its greater strength to resist the explosion, and by its greater infusibility which secured such pieces of ordnance from running at the touch-hole.

In 1612 James I. granted a patent to Simon Sturtevent for the use of coal in casting in iron, but his plan when attempted to be brought into practice totally failing, another patent was granted in the next year to J. Ravenson. The plan of this second projector was also unsuccessful, and was superseded by an improved method invented by one Dudley for which in 1619 he obtained a patent from Charles I. He erected his works at Pensent in Worcestershire and, it may be presumed, was going on successfully, since he excited the jealousy of the other smelters in the neighbourhood, who let loose on him a mob that entirely destroyed the whole establishment.

That the art of casting iron cannon originated in this country, appears from a statement by Swedenborg (Regnum subterraneum, p. 145) who says that the Duke of Nevers intending to introduce into France the art of casting iron ordnance procured skilful workmen from Sweden, but that they entirely failed of success: he then got some English smelters by means of whom he was enabled to establish in Perigord the first iron foundry. Swedenborg published his book in

1734, and in his account of the English iron works, p. 154, he states that in Sussex and Kent are many furnaces for casting ordnance. It was only in winter that they were used for this purpose, the summer iron being made into bars. Near Tunbridge was a very large furnace capable of casting two cannon in a day, each of which weighed 15 cwt. Although he does not mention the kind of fuel employed, there is no doubt that it must have been charcoal, and the well known fact that a furnace works better and gives a more fluid metal in cold dry weather than in warm moist weather explains why in these furnaces it was only in winter that they could get heat enough for a fusion sufficiently liquid to be cast into moulds.

He also says that in Lancashire and Cumberland there were many furnaces working with charcoal, that in some of them, in consequence of the scarcity of wood, peat was made trial of, but the metal produced in these furnaces proved to be sulphurous, hot-short, and of very bad quality.

High furnaces had been already introduced in the neighbourhood of Stourbridge; and the materials used in them were a mixture of iron ore (probably from Lancashire) and of iron stone the produce of certain strata of the coal measures in the vicinity. Oak charcoal was the principal fuel, but in some furnaces they had begun to mix with the charcoal *cinders*, *i. e.* coke made by burning coal in heaps in the open air; the latter however were said to diminish greatly the yield of metal in a given time, so that some furnaces which, with charcoal, had been used to pro-

duce 15 or 16 tons of iron in a week, gave with cinders only 5 or 6 tons. The only use mentioned to which cast metal was here applied is making cannon.

The state of things above described seems to relate to the very beginning of the last century, about which time a colony of Quakers established themselves at Coalbrook-dale in Shropshire, and made iron from the ore which abounds in that district, the fuel being probably furnished at first by the woods of oak and hazel which at that time choked up its beautiful dingles and spread themselves in a continued forest to the base of the Wrekin. When this fuel began to grow scarce the beds of coal were worked, and, by rejecting those that were of inferior quality and coking the others with great care, a combustible was obtained better fitted even than charcoal itself for the fusion of that particular kind of ore which is found in the coal measures. The religious principles of the Quakers however forbade them to cast cannon, the only use to which this form of iron had hitherto been applied; they therefore began to make of it boilers, fire-grates, and other articles, the parts of which, being of small dimensions, required a metal not only very fusible but of a fine grain. By the skill and perseverance of the late Mr. Abr. Darby all these objects were accomplished; and to him and his partner Mr. Reynolds are, I believe, to be attributed those improvements in the art of smelting iron with coke which now form the basis of so important a branch of national industry.

In 1760 the Carron smelting works in Scotland

were established by Dr. Roebuck, and in 1777 the first iron bridge, namely that near Coalbrook-dale, which spans the Severn with a single arch, was erected by Mr. Abr. Darby. Since that time the manufacture of coke iron has been continually extending in this country; suppressing by its superior cheapness all the furnaces of charcoal iron, and almost daily adapting itself to new and important uses. The seats of the iron smelting works are coextensive with our principal deposits of coal, with however the partial exception of the coal-fields of Durham and Northumberland. In this district the expense of raising the coal, on account of its depth and other difficulties, is greater than elsewhere, and the beds of ironstone are few and little productive.

The coal basin of South Wales yields the largest quantity of iron, next comes Staffordshire then Shropshire Yorkshire Derbyshire and North Wales. The whole of Scotland, estimated together, would occupy a place between Derby and Yorkshire.

In the year 1825–6 it was computed that in

South Wales	there were	82	furnaces in work	making	223,520 tons.
Staffordshire	,,	81	,,	,,	171,735
Shropshire	,,	36	,,	,,	86,320
Yorkshire	,,	22	,,	,,	35,308
Derby	,,	14	,,	,,	19,184
North Wales	,,	8	,,	,,	13,100
					549,167
Scotland	,,	17	,,	,,	29,200
Ireland	,,	2	,,	,,	3,000
					581,367

If to these we add the produce of Gloucestershire Durham Lancashire Cumberland and Leicestershire the sum may be moderately taken at 600,000 tons of pig iron, requiring for their production nearly three million tons of coal, exclusive of what is required for the conversion of the greater part of this into malleable or bar iron. During the last ten years the produce of iron in this country has obviously been advancing in a very rapid progress, but I am not in possession of documents to enable me to state its amount.

I now proceed to describe the process of iron smelting; and shall first notice the materials and the preparation that they undergo before they are put into the furnace. The materials are three namely the Ore, the Fuel, the Flux.

I. *Ore.*

The ore at present employed is argillaceous or clay iron ore mixed by some smelters with the rich hæmatite of Lancashire and Cumberland; but this latter even when used in small proportion is very liable to deteriorate the produce if intended for conversion into bar iron.

The argillaceous iron ore is generally called ironstone, because it bears such a resemblance in aspect to a common stone that few persons would suspect it to contain any metallic substance, except from its specific gravity being greater than that of ordinary stones. It occurs in some but by no means in all the beds of shaly or slaty clay that alternate with the

other beds of which the coal-formation or deposit consists. If we look along a section of one of these shale-beds, we shall often see that it contains one two or more subordinate beds of compressed egg-shaped masses, each mass being separated from the adjacent ones by a little clay. On attempting to take out one of them, it will often be found wrapped round with slaty clay so as to render it difficult to say where the iron ore begins and the shale ends: and in fact in such cases there is no very determinate demarcation; for the middle of each mass may be considered as a centre around which the carbonates of iron and of lime have arranged themselves in zones, being mixed with clay in proportion to their distance from the common centre. Sometimes a shell or vegetable remain seems to have determined the attraction, and accordingly many of the nodules when sharply struck in a longitudinal direction split and exhibit the impression usually of a fern leaf in great perfection. Where the centres of attraction have been numerous, the nodules of ironstone are many, small in size and rich in quality; where they have been few, the contrary takes place, and instead of nodules we find tabular masses passing insensibly into the surrounding clay, and poor in the proportion of iron that they contain.

Several chemical analyses have been made and published of these ironstones, exhibiting a very sufficient agreement on the whole, considering their actual variation from each other within certain limits. The iron in all of them is in the state of carbonate as like-

wise is the lime, and of these two, the first always is the most abundant of the component parts of the ore and the second often stands the next in proportion. Small quantities of the carbonates of manganese and of magnesia likewise occur; the latter, if amounting to two or three per cent., rendering the ore difficult of fusion. Of the two other ingredients silica and alumina, the former is three or four times as much as the latter, and their respective proportions to the metallic part of the ore vary according to the circumstances that I have already explained. Other casual ingredients are iron pyrites and blende or sulphuret of zinc, and a little titanium. The limits of variation of the percentage of metallic iron in the raw ore may be stated at from 27 to 38. The ironstone when picked out of the clay is, or ought to be, stacked and exposed for a winter to the weather, during which the outer coating of the nodules, which contains the least iron and the most earth, cracks and falls to pieces, leaving the rich nucleus of a dusky brown colour.

The next process to which the ore is subjected is roasting. For this purpose it is either put into kilns or made into ridges in the open air, being mixed with about $\frac{1}{4}$ of its weight of small coal, *i. e.* 5 cwt. of coal to 1 ton of raw ore. Roasting in ridges occupies from a week to ten days and, as the heat is rarely above a low redness, though the whole of the moisture is driven off, from $\frac{1}{6}$ to $\frac{1}{3}$ of the carbonic acid remains, but any pyrites accidentally mixed with the ore is for the most part decomposed, the loss of weight in this process amounts to about $\frac{1}{4}$; a ton therefore of raw

ore gives 15 cwt. of roasted ore which, according to its quality, should give from 34 to 46·5 per cent. of cast iron. The difference in appearance between the raw and roasted ore is remarkable; the former is gray or brown and is not attracted by the magnet, the latter has a dry feel, adheres strongly to the tongue, is cracked in all directions, has a slate-blue colour and acts powerfully on the magnet. It should be carried to the furnace as soon as possible, or if kept should be carefully protected from the rain.

II. *Fuel.*

The fuel employed is coal brought to the state of coke by charring in ovens or in the open air. By the former method a greater quantity of coal is obtained, and it has likewise the advantage of being more solid and compact; but the latter method gets rid more completely of the sulphur which all coal contains, more or less, in the state of iron pyrites. In every colliery are some seams, often those nearest the surface, which are too sulphurous to be used advantageously by the smelter under any circumstances; and, where he has a choice, those that are the most free from sulphur are to be preferred.

The proportions of coke given by equal weights of coal differ exceedingly, not only according to the way in which they are prepared but according to the quality of the coal. Some of the South Wales coals contain but just enough of bitumen to enable them to undergo the process of coking, and such will yield from 66 to 83 per cent. of coke made in the open air. The

coking coal of Newcastle and of Staffordshire gives from 60 to 61, while the free burning slaty coal of Staffordshire Shropshire Yorkshire and Glasgow gives only about 50, and those varieties that approach to candle coal give scarcely 40. The proportion of earthy matter in all coals fit for being coked may be stated as rarely exceeding 6 or 7 per cent.

III. *Flux.*

The only flux that is used is lime; which, by combining in the furnace with the other earthy ingredients of the ore and of the coke, disposes them to form an easily fusible slag or glass through which the particles of melted metal may subside by their superior gravity. The lime is used in the state of carbonate, or in other words of limestone, and requires no other preparation than that of being broken into pieces of a convenient size. The purest limestone is in general that which answers the purpose best: those varieties that contain magnesia are to be most carefully avoided.

The lowest bed of the coal-formation usually rests on limestone, and in the coal-formation itself are found not only the ore and its most appropriate fuel, but the pebbly grits which afford the blocks of refractory stone necessary for building those parts of an iron-furnace that are required to endure the utmost extremity of heat, as well as those seams of refractory clay of which the fire-bricks are composed with which the middle and upper parts of the furnace are lined. Thus, many situations in this favoured island may be pointed out in which all the above mentioned mate-

rials occur almost on the same spot; and when to this is joined the convenience of water carriage, as happens in many places, that man must indeed be of an obtuse understanding and churlish temper in whom this wise arrangement and prodigal beneficence of nature fails to produce corresponding feelings.

Having prepared our materials for the furnace it is now time to describe the furnace itself. Its form (see the head-piece, p. 258) is that of a truncated quadrilateral pyramid about 50 or 55 feet high. The outer part is of brick or squared stone with contrivances to obviate the danger of its cracking by the expansion that takes place when it is heated, and it is lined with two courses of fire-bricks having a layer of pounded coke between them to prevent the escape of the heat. The interior or cavity may be divided into the following parts from below upwards, as shown in the engraving prefixed to this paper. First the hearth *a*, about two feet high; its base and sides are formed of massive blocks of coarse pebbly gritstone as being the most infusible of all common building stones. Upon this is erected the crucible *b*, a four-sided cavity between 6 and 7 feet high slightly enlarging upwards so as to be at top about $2\frac{1}{2}$ feet wide: the part above, called the boshes *c*, is in the shape of a funnel or inverted cone about 8 feet high and twelve feet wide at the top. On this is placed the great cavity of the furnace *d*, of an irregular conical form about 30 feet high and gradually narrowing so as to be only about 3 feet in diameter at the top. From this part it enlarges into a funnel-shaped chimney *e* about 8 feet high in which is cut a

large square aperture through which the charge is thrown from time to time into the furnace. About two feet above the hearth is an aperture *f* through which the blast-pipe or *tuyere* is introduced. Sometimes there are two opposite tuyeres and occasionally even three.

A well built furnace will last in constant heat from four to six years before it will be necessary to stop it for the purpose of repair. One of the ordinary construction will produce about 50 tons of metal in a week, but in South Wales an increased width is generally given to the furnaces some of which will yield from 80 to 100 tons per week.

I now proceed to consider what takes place in the furnace when it is at work; and, passing by the precautions necessary to dry the furnace and to heat it very gradually in order to prevent the masonry from cracking, we will suppose the furnace to be filled with burning coke, the blast to be let on, and everything prepared for regular charging.

The charge consists of coke, roasted iron stone, and limestone in certain proportions and thrown in at certain intervals: these intervals are shorter or longer according to the quantity of materials in each charge, and I believe the best practice is to charge frequently and in small quantities at a time. The object of the smelter is to separate the whole, or at least as much as possible, of the iron contained in the ore, not merely in the metallic state but combined with carbon in greater or less proportion according as he intends it for casting or for conversion into bar, the former

requiring the larger and the latter the smaller proportion of carbon. But this apparently simple object requires the concurrence of a great number of chemical actions several of which have been but little investigated.

As the chief condition absolutely requisite to produce the intended effects is a high increase of temperature, and as this depends on the quantity and state of the air or blast, which, entering the furnace at the tuyere hole, passes out through the top of the furnace, and in its passage excites intense heat by combining with the carbonaceous part of the coke, it will be better to begin with the consideration of this agent. The air passes into the blowing machine from the atmosphere, and of course at the same degree of density temperature and moisture as the external air of which it forms a part. When in the blowing machine, the air undergoes compression, and at the same time a quantity of latent heat in proportion to the diminution of volume is separated, raising the temperature of the blowing machine itself and escaping ultimately into the outer air. When the compressed air is delivered from the end of the tuyere pipe, the pressure to which it had been subjected being thus removed, the air instantly resumes its original volume and in so doing renders latent a quantity of heat. Part of this it takes from its own sensible heat and thus reduces its thermometrical temperature. The blast therefore enters the furnace at a lower degree of heat than that of the outer air, and this difference is the greater in proportion to the amount of the pre-

vious compression. The average atmospheric pressure is 14·75 pounds on every square inch of surface, and the compression which the air undergoes in the blowing machine varies in the English iron works from $1\frac{1}{2}$ to $1\frac{3}{4}$ pounds. In Scotland the working pressure seems to be much greater, $2\frac{1}{2}$ and even 4 pounds being recorded. Mr. Mushet states as the result of actual experiment, that while the heat of the outer air was from 60° to 70° Fah. the temperature of the blast as shown by a thermometer held in it was as low as 38° Fah. Messrs. Coste and Perdonnet* who mention a furnace near Glasgow as working with a blast of 4 pounds, state that the weekly product of iron was increased nearly $\frac{1}{5}$ simply by lowering the pressure, or in other words by diminishing the quantity and at the same time increasing the temperature of the blast.

In common life we are so apt to consider the air as having no sensible weight, that we do not readily admit the idea of a furnace into which are thrown several tons of solid materials in 24 hours, being at all affected in its temperature by that of the air which passes through it. If however we compute the volume of such air and then estimate its weight, we shall be somewhat surprised to find that it far exceeds the sum of the weights of all the solid ingredients.

In a furnace near Glasgow working under high compression, the volume of air thrown in (when reduced to atmospheric pressure) is estimated by the above-mentioned gentlemen at 6292 cubic feet per

* Annales des Mines for 1829.

minute, the weight of which in 24 hours would have amounted to 6192 cwt. while the whole weight of the charges of coke ore and limestone during the same period was no more than 666·5 cwt. the weight of the air therefore was to that of the charges as 9·29 to 1. This however may be considered as an extraordinary case; but in common practice the weight of the air is at least 4 times as much as that of the charges.

The only use of the air in the furnace is to excite the necessary degree of heat, and this is effected by the combination of the oxygen of the air with the carbon of the fuel; but, part of the carbon is wanted to reduce the magnetic oxide of iron, such as it exists in the roasted ore, to the metallic state, as well as to combine with the metal, when reduced, so as to form of it cast iron of good quality. In estimating therefore the quantity of air required, we must first ascertain the weight of the pure carbon in the coke, which in a general way may be stated at 0·9 of the entire or rough weight. From this we must deduct the carbon required for combining with the oxygen of the iron ore and with the iron itself, and the remainder multiplied by 11·75 will give the weight of atmospheric air required for the full combustion of the fuel, supposing the whole of its carbon to be converted into carbonic acid.

We will now consider the mutual action on each other of the elementary substances that compose the three ingredients forming the charge or burden as it is sometimes called, of the furnace. Regarding these I shall first make one general observation, namely

that the carbonic acid of the limestone is the only substance of the whole separable from its combination by mere heat; and, as the coke ore and limestone are in irregular pieces of some size, they can touch one another only by a few points; and that the commencement at least of their mutual action must be effected by means of some gaseous matter.

There is always a yellowish blue lambent flame playing over the top of an iron furnace in its ordinary state of work, showing evidently the escape of combustible gas of some kind or other, and that, of the oxygen of the blast, none or scarcely any, has been able to penetrate in an uncombined state through the superincumbent mass of hot materials about 40 feet in thickness. Of the nature of this combustible gas we are wholly ignorant. It may be carburetted hydrogen from the decomposition of water dissolved in the air, or carbonic oxide, or perhaps even cyanogen, or a mixture of all three. On all these suppositions however it is a gas containing carbon in a state fitted to decompose the oxide of iron and bring it to the metallic state. A charge put on to the top of the furnace takes from 48 to 60 hours in descending low enough to come within the direct action of the blast, nor can the iron of the ore in less than that time combine with a sufficient quantity of carbon to produce No. 1 metal, because it is to be presumed that during the whole of this time the ore is still in pieces of nearly the same size as when it was first put in, and therefore that the interior particles of each piece can become carbonised only by absorbing carbon from

the outer particles, in the same way as steel is made from the cementation of iron bars. The limestone probably undergoes no change except that of parting with its carbonic acid, either by the mere action of the heat or brought to the state of carbonic oxide by the concurrent action of heat and carbon.

The coke probably continues to be slowly losing carbon by the action of the gases that percolate through it from the time of its becoming red hot; but scarcely undergoes combustion by combining with the oxygen of the blast till it has arrived near the great focus of heat which is just within the boshes. Each charge therefore as it subsides in succession to this part of the furnace still remains in the same detached pieces as when it was first put in, and the chief chemical changes are, that the iron has exchanged its oxygen for carbon, that the limestone has become quicklime, and that the coke has lost some, but not much, of its combustible ingredient. The direct action of the blast however soon materially changes this state of things. The coke begins to burn rapidly vividly and with the production of intense heat, the lime combines with the earthy parts of the ore and also with those of the fuel producing a fusible glass or slag, which envelopes the particles of carbonised iron and protects them from the direct chemical influence of the blast, to which effect likewise the fuel concurs by offering its own carbon to the action of the air in a state better fitted to combine with the oxygen than the carbon combined with the iron or even the iron itself. In proportion as the above-mentioned ingre-

dients enter into fusion the mixture sinks down into the crucible and soon gets below the action of the blast.

The proportions in which the three ingredients, ore, fuel and flux, are mixed in the furnace vary greatly. One of the causes of variation is the kind of iron which the smelter wishes to produce; No. 1 or highly carbonized iron for castings, requires a greater proportion of fuel than No. 2 iron for making into bar, both because the former is combined with more carbon than the latter, and because a more liquid fusion is required for casting than for pig-metal. Certain kinds of ore produce a metal more fusible at a given temperature than another variety in an equal state of carbonization, the former therefore will require a smaller consumption of fuel. It is obvious likewise that the required proportion of limestone will vary according to the quantity of carbonate of lime already existing in the ore, and to the proportion of the other earths as well as of their kinds.

In Scotland the proportion of coke to ore is in general high, but almost the whole of the Scotch iron is used for castings, and the proportion in England for castings is nearly the same. In South Wales and Staffordshire, the iron of which is chiefly used for bar, the proportions of coke to ore are nearly equal. The limestone is usually in the proportion of from 10 to 12 per cent., but occasionally is considerably higher. The following table shows the respective centesimal proportions of the three ingredients.

Coke.		Ore.		Limestone.	
54·6	..	35	..	10·4	Glasgow average.
52·4	..	36	..	11·6	Butterley, for castings.
48	..	36	..	16	Newcastle, for castings.
44·5	..	44·5	..	11	Neath Abbey.
45	..	45	..	10	Shropshire and Staffordshire.
46·5	..	43·5	..	10	Lightmoor.

I now return to the contents of the furnace after they have undergone the action of the blast. They are now divided into two distinct substances, namely the melted iron which, as being the heaviest, occupies the hearth; and the vitreous scoriæ or slag that floats on it, defending the iron from any part of the blast that may be reflected downwards and overflowing gradually at an aperture in the crucible in proportion as the quantity of iron accumulates below. The different appearances of this slag indicate very correctly to the smelter the working of the furnace. If its colour is yellowish white without any transparent or glassy parts in it, all is going on as well as possible; the pale colour indicates that there is no sensible quantity of iron remaining in the slag, and the absence of glass that the lime is in due proportion. The most general appearance however of the slag is that of an opaque but distinctly shining vitreous mass, with more or less of an intermixture of green forming streaks and waves. In this case there is some, though but a very small portion of, oxide of iron remaining in the scoriæ, probably in the state of silicate of iron and indicating a small deficiency of lime, the chemical action of this latter being, appa-

rently, to saturate and neutralize the silica and thus prevent it from retaining any oxide of iron. The observations of Mitscherlich may be considered as corroborating this view of the matter, as he found by analysis that iron slags consist chiefly of the bisilicates of lime and magnesia, with traces of bisilicate of iron. Streaks of blue in the scoriæ indicate the presence of protoxide of iron, probably, only mixed with or diffused through the other ingredients but not in a state of chemical combination with them. If these are prevalent they show either a deficiency of fuel, or which comes to the same thing, an excess of blast, and are accompanied by a corresponding reduction in the quantity of iron produced. This deterioration may also be occasioned by a change in the atmosphere from dry to moist, in which case the water is decomposed and both its component parts the oxygen and hydrogen combine with and carry off portions of carbon. If the slag is dark coloured and heavy, this is the worst indication of all. It shows that a large proportion of iron is coming away in the slag and that the remainder will be found defective in carbon, consequently unfit for casting and likely to afford bar of a hard, harsh and brittle nature. It may be considered as indicating either a deficiency of coke, or which is its most usual cause, a too rapid working of the furnace; so that the ore has not had time to become duly carbonized before it arrives within the action of the blast. The remedy for this is to diminish the quantity of air thrown in and consequently to work slower.

When a sufficient quantity of melted iron has collected in the hearth it is discharged or run out; and this happens generally twice and sometimes thrice in 24 hours. If the metal is intended to be used immediately for castings, it is taken out by hand ladles and put into a large iron bason with a long handle to it, the ladles and bason being lined with clay to prevent the liquid iron from melting them. The bason is then raised by a crane to a convenient height and, being brought over the main aperture of the mould or moulds, a skilful workman tilts the bason by means of the long handle so as to pour its contents into the aperture. If however the iron is not used on the spot, it is run into pigs, which are afterwards either again melted for castings or are made into bar by processes which I shall hereafter describe. The pigs are merely blocks formed by letting out the metal into furrows made in sand. When the furrows are so arranged that there is one of large size from which smaller ones go off at right angles the large one is called a sow and the others the pigs; but at many furnaces the furrows are all of the same size and the blocks cast in them are called pigs or pig-metal; the usual weight of a pig of iron is about 180 lbs.

Three or four kinds of cast iron are distinguished in the market.

No. 1 iron is peculiarly fitted for castings; it contains more carbon than the others, is more fusible, and from requiring a larger proportion of fuel in the furnace costs more to the smelter and therefore bears a higher price in the market. As it runs from the

furnace its surface becomes almost immediately covered with a black matter called *kish*, which is usually considered to be a variety of plumbago. Parts of it however have evidently a crystalline structure and such reflect the light which falls on them with great brilliancy and vivacity and are hard enough to scratch glass. It has not been analysed. Iron while in the furnace is at an intensely high temperature and also under the heavy pressure of the scoriæ, and in this state seems capable of combining with a larger quantity of carbon than it can retain at a lower melting heat, on which account, till it becomes solid, this kish is continually rising to the surface, but in smaller and smaller proportion as the metal becomes cooler. The larger the mass of metal of course the slower it cools; and, agreeably to the usual rule in such cases, the structure is more decidedly crystalline: hence it is that of the same running the sow presents a far more crystalline structure than the pigs; and of either one or the other of these masses the middle portions are more highly crystalline, or in coarser grains, than near the surface. The colour of such metal is dark gray approaching to black; the finer grained it is the lighter is its colour though it has undergone no chemical change whatever. On this account those pigs of a casting that are nearest the door or open air are covered up as quickly as possible with sand and coke dust lest they should, by cooling too rapidly, become of too light a colour by acquiring too fine a grain. Metal less highly carbonized than No. 1, however slowly it may be cooled, has always a light colour;

and as the purchaser forms his judgment of the quality of the iron in part from the colour, this is evidently an ambiguous test operating in favour of the purchaser and against the seller.

No. 4 iron when it has become solid will be found covered with a scale of black magnetic oxide, the surface is generally concave and more or less honeycombed; when broken it presents a texture nearly compact and its colour is iron gray or sometimes mottled.

Nos. 2 and 3 pass by insensible degrees into the two extremes already mentioned, and the minute differences by which they are distinguished require no notice on the present occasion.

The existence of a large quantity of carbon or plumbago in certain varieties of cast iron may be proved by submitting them to the long continued action of very dilute acids, which will dissolve out the iron leaving nearly the whole of the carbon behind. Sometimes fortunate accidents occur which, so to speak, dissect out the iron in the course of time leaving only the carbon behind but still retaining the form and size of the original piece of iron. Thus, a piece of cast iron which had fallen to the bottom of a brewer's vat in London was taken out again after three or four years, and the whole upper surface is now soft and in the state of plumbago.

In proportion to the quantity of carbon that cast iron contains is its softness and fusibility. But the iron of different districts, even apparently in the same state of carbonisation, differs considerably in fusibility.

Thus No. 1 Staffordshire iron is less fusible than No. 1 Derbyshire iron, and accordingly iron pipes are cast much thinner in the latter county than it is possible to make them in Staffordshire. Hence we may infer that the most fusible of these irons contains something which is not to be found in the other, and that therefore the Staffordshire iron may be regarded as the purer of the two, though this very purity for some purposes may be a disadvantage. We know that both phosphorus and sulphur remarkably increase the fusibility of iron, and the presence of either or both of these substances may make the difference between the two kinds of cast iron. This superior fusibility however is obtained at the expense of an increased degree of brittleness, which renders such iron quite unfit for bearing strains and sudden shocks. The Prussians of late years have taken advantage of a very fusible iron that they possess, by making it the basis of cast ornaments remarkable for their beauty and extreme thinness and also unfortunately for their great brittleness. Much of the iron ore in Prussia is of the kind called by mineralogists bog iron ore, which lies in beds near the surface and is well known to contain phosphorus. The bog ores in England have been neglected on account of the bad quality of the iron that they yield, but if it should be a matter of any importance to a manufacturer to imitate or rival the Berlin castings, the most likely way to succeed, as far as the quality of the metal is concerned, would be to make it from bog ore or native ochre.

The time allowed for an illustration obliges me to

postpone the remainder of this subject to a future opportunity, I shall therefore only trespass on your indulgence to say a few words on the new method of working iron furnaces with hot air and raw coals.

If the loss of weight in coking a parcel of coals be one half, which is about the general average, and if the half that remains includes the whole of the earthy matter originally existing in the coal, and which computed on the coke amounts to about 10 per cent., it follows that only 40 of carbon are obtained from 100 of coals. Of the 50 per cent. volatile matter a large proportion, it is not easy to say how much, is combustible, and in a state well calculated to deoxygenize the iron contained in the ore. But, together with the combustible gases, a considerable quantity of aqueous vapour is produced which, by cooling the whole upper part of the furnace, would in a great measure defeat the expected benefit from the combustible gases. To avoid this difficulty the air has been passed through iron pipes surrounded with fuel so as to give it a high temperature before it entered the furnace. By this contrivance the heat of the furnace has been kept up, and iron has been obtained by the use of raw coal * at an almost incredibly less expenditure of fuel.

The furnaces of Scotland seem to have benefited more than any others by this invention, both because their coal loses on an average more in coking than that of other districts and because they have generally

* Caking coal will not answer for this purpose, as it is liable to concrete in the furnace and interrupt the regular descent of the burthen.

been in the habit of employing rather a large proportion of fuel to their ironstone. It may also be remarked that they have heated the air of the blast to a greater degree than has been practised elsewhere.

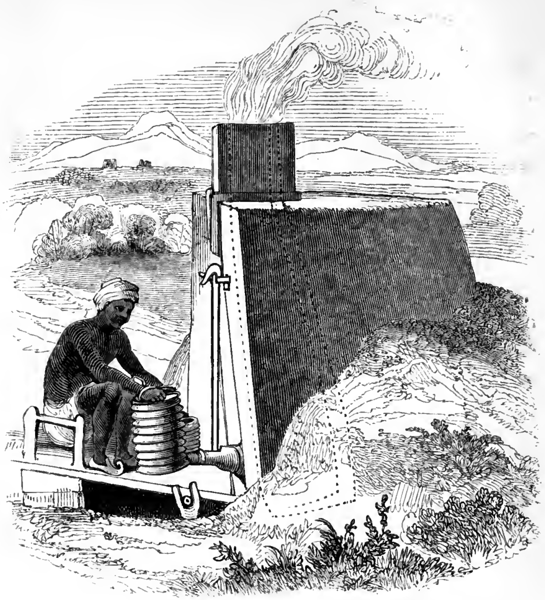
An experiment made on a large scale at the Clyde iron-works in Feb. 1833 gives the following results as compared with the working at the same establishment in Feb. 1829. In the latter 1500 tons of coke (3750 tons of coal) gave, by the usual process, from 879½ tons of ore, 500 tons of cast iron. In the former 1032 tons of coal with 951½ tons of ore gave 505 tons of iron. The air was thrown in at the temperature of 612° F. about equal to that of melting lead. Here is therefore a saving of two-thirds of the coal. But if we advert to the quality of the metal produced we shall find that while the old process gave 222½ of No. 1, 145½ of No. 2 and only 129 of No. 3, the new process gave 150 of No. 1, 90 of No. 2, and 260 of No. 3.

At the Butterley works, where the temperature of the blast was only 360°, the saving in coal seems to be one-half and of ore about one-fifth, the quality of the metal being stated as dark gray for casting.

At Wednesbury in Staffordshire the saving in coal seems to have been about one half, the quality of the metal a mixture of No. 1 and No. 2, the temperature of the blast was 360°.

That by the adoption of the new process, a great saving of coal will be made appears quite certain; but it seems also equally certain that the quality of the iron will be lower and perhaps in a very great degree. In

the present enormous demand for iron, almost beyond the power of the trade to supply by the usual method of smelting, this new invention is likely to be extensively adopted, and the purchaser must be content to accept iron of a lower quality in consideration of his orders being quickly executed. When however the present demand shall relax and the iron masters come into competition with each other for customers, the new process will be reduced to its true value; but what that is, cannot in the present state of things be known with any correctness.



METALLURGICAL HISTORY OF IRON.—Part II.

BAR IRON.

In a former illustration I treated of cast iron, such as is made in this country from argillaceous ore smelted with coke or with coal, and I described the successive details of the process whereby are obtained the several varieties of cast iron that are to be found in the market. I perhaps, therefore, in strict order, ought now to proceed with the method of reducing forge-pigs to bar iron. But, on mature considera-

tion, I think that I shall be following a more natural order by first explaining the different methods whereby bar iron is obtained from the ore by the use of charcoal; both, as these methods are more simple than those in use at our own forges, and as they have been in practice from the remotest antiquity. I shall therefore in this and the next illustration treat of the preparation of bar iron in general; beginning with the most simple and rudest processes for obtaining the metal in this state, and ending with the more complex and difficult ones.

The properties of iron which it is especially necessary to bear in mind for explaining the different methods of getting this metal in a malleable state are the following, namely, 1, the high temperature necessary for its fusion; 2, the soft and pasty state to which it is brought by a white heat, so that if two pieces are laid on each other and strongly hammered a perfect incorporation of them is produced: this process is called welding: 3, the chemical attraction which exists between iron and carbon producing a compound far more fusible than iron itself and which may be decomposed in various ways, the iron remaining pure, and the carbon separating either in a solid state or in that of an inflammable gas or of an acid one.

In all the ores of iron, either as offered by nature or as they are prepared, by roasting, for the furnace, the metal is in the state of oxide; and therefore, as far as the iron itself is concerned, the production of bar iron is simply the separation of the oxygen with

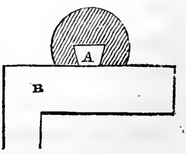
which it is combined in the ore. Now, to decompose pure and pulverulent oxide of iron is one of the simplest of chemical processes, nothing more being necessary than to put the oxide into a glass tube, to bring it to a low heat less than redness and then to pass dry hydrogen gas through the tube: the hydrogen combines with the oxygen producing aqueous vapour, and metallic iron remains. At a moderate red heat the same effect will be produced if finely powdered charcoal be mixed with the oxide of iron instead of employing hydrogen, and if it were possible in this apparatus to raise the heat up to the welding point of iron, there would be no difficulty in bringing the separate particles of metal into contact and thus obtaining a small piece of malleable or bar iron.

A process nearly equalling this in simplicity is said to have been formerly in use in the island of Elba; the ore employed was iron glance, which when carefully selected rarely contains more than three or four per cent. of earthy impurities, it was broken into small pieces and imbedded in charcoal on the floor of a reverberatory furnace, and, after the oxygen had been separated by the action of the charcoal, the temperature was raised to a glowing white, the pieces of ore, now in the state of porous iron, became of a pasty consistence, were made to adhere to each other by hammering, and were then drawn down into bars in the usual manner. Mr. Mushet, if I am not mistaken, repeated this process by way of experiment some years ago with full success, using compact hæmatite instead of iron glance.

We know from historical documents that iron has been made in India from the remotest antiquity; and, from the rudeness of the process followed there at the present day, may infer that it is still in that country nearly in its primeval state, being rendered thus stationary partly from the institution of Castes, and partly by the despotic corrupt and turbulent sovereignties by which India has always been swayed, and which, by preventing the accumulation of private capital, has likewise prevented advance in those arts which require any considerable outlay in order to be carried on to the best advantage. The printed works of Buchannan and Heyne contain, among a mass of other valuable matter, many interesting details respecting the manufacture of iron in India which I have freely consulted, and by the accustomed liberality of the East India Company I have been favoured with the perusal of a very valuable manuscript on this subject by Major James Franklin, as well as with the loan of specimens.

All the Indian furnaces are on the same general construction, differing only in size and in the relative proportions of some of the parts. I shall therefore describe in detail sufficient for my present purpose, from Major Franklin's papers, those which are used in central India.

Fig. 1



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In the annexed ground plan, fig. 1, B is a trench three feet deep having a sloping entrance, and A is the furnace, the shaded part showing the comparative thickness of

the walls which are made of large unburnt bricks and lined with clay.

In figs. 2 and 3 are represented a front elevation and section of the furnace. The first thing that

Fig. 2.

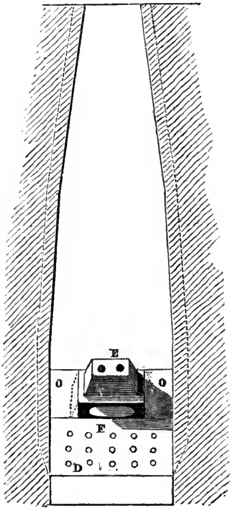
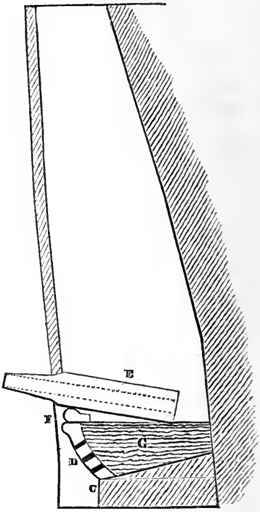


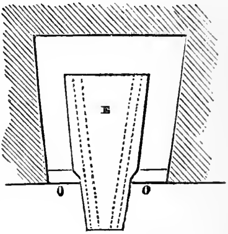
Fig. 3.



strikes the eye is the obliquity of the furnace as seen in fig. 3 which is an essential condition in its construction. C is a large block of sandstone or some other hard and difficultly fusible rock: its surface slopes towards the front in order to direct the melted matter to the perforated earthen plate D, the holes in which are opened from time to time with an iron bar in order to let out the melted slag or scoriæ: E is the

tuyere or blast-pipe composed of two diverging earthen tubes inserted into a mass of dried clay: fig. 2 shows a front view of the part, fig. 3 a section; and fig. 4 a plan of the same; this latter likewise shows how large a proportion it occupies of the area of the furnace at the place where it is inserted.

Fig. 4.



F, figs. 2 and 3, is a wedge of clay on which the tuyere rests and by which its angular position is adjusted, while the end of the tuyere rests on G a mass of cowdung and chaff with which the bottom of the furnace is filled previous to a smelting. O O fig. 4 are plates of burnt clay or thick tiles that fill up the space in front of the furnace not occupied by the tuyere. The bellows are made of skin and are two in number, and a pipe projecting from the bottom of each is united with the blast-pipes of the tuyere. These bellows are placed on a plank laid across the trench in front of the furnace, at the further end of which is seated a man who, by working the bellows alternately one by the right and the other by the left hand, produces a continued stream of wind, as seen in the view at the beginning of this paper. The same view also shows the proportion which the chimney bears to the body of the furnace, as well as an ingenious contrivance to prevent the tuyere from rising when the bellows are drawn up. This con-

trivance is a bar the bottom of which presses on the end of the tuyere while its top is hitched into a loop of iron placed between two lateral studs or staples. The entire height of the furnace varies from 4 feet 4 inches to 8 feet, and its diameter at the widest part from 1 foot to 3 feet 9 inches.

Although it is probable that argillaceous iron ore exists in India because we know that coal occurs in that country, yet as no coal mines have hitherto been worked there to any extent, it is no wonder that the repositories of iron in the coal formation should remain unexplored : nor indeed would the Indian smelter with his imperfect means be able to smelt common iron-stone to any profit. The ores actually used may be arranged under three species, and are found either in the neighbourhood of the Ghauts or at the foot of the higher mountains that run nearly parallel to them but at a greater distance from the coast.

1. *Magnetic iron sand.*

Of this there are no proper mines, but it is met with in considerable abundance in the beds of torrents that descend from the trap and granite mountains with great impetuosity during the rainy season, loosening and rolling down with them fragments of stone which serve like battering-rams to disintegrate and tear up the rocks against which they impinge. The iron ore seems to be dispersed through the rock in the form of crystals and small grains, which being separated from their matrix by this natural process of washing over are from their greater specific gravity

deposited in the pools and holes of the stream little mixed with earthy matter. Together with the grains of iron are other grains of nearly the same specific gravity consisting chiefly of an ore of Titanium which the native smelters never attempt to separate. The iron sand when pure yields by analysis from 79 to 85 per cent. of oxide of iron and from about 9 to 15 of oxide of Titanium. From its not being found in mass or in proper mines it is smelted only in one or two places in Europe; but the bar iron which it affords under European management is of good quality and belongs to the harder varieties of this metal.

2. *Specular iron or iron glance,*

Occurs in beds of no great thickness alternating with thin laminæ of sandstone; not unfrequently by decomposition, or more probably by disintegration, it is found in blood-red masses of an earthy aspect with scales of unaltered specular iron intermixed. When pure it contains nearly 90 per cent. of oxide of iron. The metal obtained from it is rather hard but in other respects of good quality.*

3. *Carbonate of iron.*

In a more or less decomposing state and passing into yellow hydrate and brown hæmatite. The ore when pure contains from 56 to 63 per cent. of oxide of iron with from 34 to 36 of oxide of manganese

* 100 of specular iron from Jabalpur with 82 of charcoal gave 41 of crude iron; 100 of red decomposing specular iron from Jowli with 89 of charcoal gave 41·5 of crude iron.

(you will be pleased to observe that the amount of metal contained in the above three kinds of ore is deduced from the analysis of European specimens, as those of India have not been examined with sufficient accuracy). This affords an excellent iron, and the celebrated Indian steel called Wootz is made from an ore of this species.

In preparing these ores for the furnace they are merely broken into small pieces and the iron sand is sometimes washed in order to free it from the lighter and earthy particles. The process of roasting the ore previous to fusion, although generally considered in European practice as essential to the produce of good iron, is not at all used in India.

The fuel is universally charcoal, that from the bamboo being by long experience greatly preferred to any other. No lime or other flux of any kind is employed. It is easy to see why, in the absence of flux, bamboo charcoal always gives the best results.

Bamboo is nothing more than a gigantic grass, and like the smaller grasses and corns of our own country is covered externally with a hard glossy varnish—this varnish is silica; it likewise, in common with all other land plants, contains potash; and as it is very possible by a dextrous application of the blow-pipe to burn off the combustible matter of a piece of wheat straw and melt the residual silica and fixed alkali into a drop of glass, so probably the same thing would occur with a twig of bamboo, this kind of charcoal therefore may be considered as furnishing not only fuel but a very active and excellent

flux. The minor details of the process vary in different works, but they all agree in charcoal only being put into the furnace at first in order to bring it up to a proper heat, and then in the ore and fuel being added alternately to the end of the operation, the proportion of fuel to ore being two measures of the former to one of the latter in the Northern Circars, where they smelt a fusible hydrate and obtain an excellent steely iron; and being 16 of charcoal to $5\frac{1}{2}$ of more refractory titaniferous iron sand in the Carnatic.

At the end of from 6 to 12 hours according to the size of the furnace the tuyere is for the most part melted and is no longer serviceable; this first part of the process is therefore necessarily finished, and on breaking down the front of the furnace there is found a mass of crude iron weighing from 24 to 100 lbs. which is drawn out by strong tongs while still hot and is divided by a hammer and chisel into two nearly equal blocks. This crude iron is of a greyish white colour, is very porous the cavities being filled with charcoal and slag, is sometimes quite brittle but generally malleable in a slight degree, and if, during the last four hours of the furnace being in activity, no ore, but only charcoal has been added, is found sufficiently malleable for common uses after being merely drawn down by the hammer into small bars. This crude metal has never been in a state of actual fusion; the Indian furnaces from their small size, from their thinness which allows a rapid escape of the heat, and from the comparatively inefficacious hand bellows

made use of, not being capable of receiving or retaining a sufficient intensity of heat to produce this effect. A remarkable proof of this occurred, according to Buchannan, at the iron-works near Savanadurga. The Sultan Tippoo, being much pressed at one time for cannon-balls and not being able to obtain any from Europe, ordered some to be made at these forges; but the workmen not being able to melt the iron had no other way of fulfilling the Sultan's orders than by hammering this half malleable crude iron into round masses as well as they were able.

To refine the crude iron a furnace is made use of such as is shown in the heading of the next paper, which exhibits not only the outside of the furnace but, by dotted lines, the interior also.

The block of crude iron is laid, covered with charcoal, on the ledge of the chimney with one end projecting a little just above the mouth of the tuyere. In this situation the end of the block soon softens and then falls down in a state of half fusion; a man with an iron bar then draws the remainder of the block a little forwards, advancing it from time to time till the whole has sunk to the bottom of the furnace. It is now dragged out while glowing hot and hammered on an anvil to separate most of the scoriæ; is then subdivided into two or three pieces, is heated and again hammered, and this process is repeated till the iron is quite malleable.

There appears to be a prodigious difference in the proportion of best malleable iron obtained from the same species of ore at different forges, and this in all

probability depends on the proportion of charcoal used and on circumstances which only local observation can duly appreciate. Thus a forge in the Carnatic working magnetic sand, from 100 parts of crude iron gave 70 of malleable iron, while a small furnace in the Mysore working the same kind of ore gave only 37 of malleable from 100 of crude. In the easier reducible ores such as the manganesian hydrate there is a much greater accordance; for, while a furnace in Jabalpur gave 70 of malleable from 100 of crude, another in Mysore gave 78 of malleable from 100 of crude iron.

If we enlarge the Indian furnace so as to enable it to work a ton of iron at a time, and replace the hand-bellows by others nearly of the same construction but larger and actuated by a water-wheel, we shall have almost an exact representation of the ancient furnace of Stiria, a district celebrated in the time of the Roman republic under the name of Noricum for the admirable quality of its steel and iron. Many of these furnaces were still in use when M. Jars an eminent French metallurgist visited that country about the year 1750. Their height is from 10 to 12 feet and the dimensions of the base are about 4 feet square and the depth below the tuyere is about $2\frac{1}{2}$ feet. The only aperture, besides that at top of the furnace, is one at the back, about 4 feet wide by $2\frac{1}{2}$ high. This is walled up, when occasion requires, with loose bricks leaving an opening for the nose of the bellows from which the blast is conveyed through a tuyere pipe of clay to the interior of the furnace. The crucible being lined with clay and pounded charcoal, a suffi-

cient quantity of charcoal is thrown in and the blast is let on; then follow alternations of roasted ore without any flux, and of charcoal, till the forge-master conceives that the crucible is beginning to fill with metal and with slag. Holes are then opened with an iron rod between the moveable bricks that compose the lowest row to allow the slag to run out; this being done they are closed and are again opened and closed as occasion may require. In about 15 hours, 45·5 quintals of ore will have passed into the furnace, no more charge is then added, the charcoal burns till it is nearly consumed, the pipe of the bellows is withdrawn and the bricks with which the upper part of the hole in the side of the furnace was closed are taken down. The remainder of the charcoal is then taken out with iron prongs and together with them come out from five to six quintals of iron in lumps mixed with slag. At length there is discovered at the bottom of the furnace the remainder of the metal in a single mass weighing from 13 to 14 quintals. This by reason of its weight and heat is got out with some difficulty and, being covered with charcoal powder as well to keep in its own heat as to protect the men who are at work upon it, is dragged to a convenient part of the building where it occupies two men for more than an hour in dividing it into two pieces by means of wedges and sledge hammers. Thus the proportion of crude iron afforded by the ore employed is about 44 per cent.

The outer part of this mass is in the state of

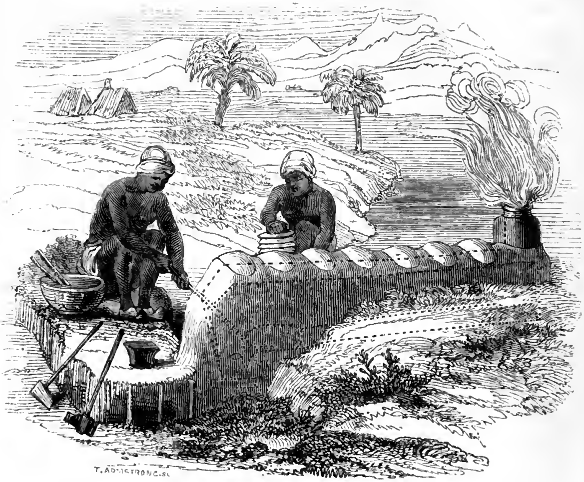
malleable iron, and, in the act of cleaving, it separates from the inner portion which is in the state of what is commonly, but not quite correctly, called native steel, for which, in the earlier ages when the manufacture of steel by cementation was unknown, the Stirian forges gained a high reputation. A person accustomed only to the high furnaces in this country would have expected the production of cast iron from the process that I have described; that is, he would have expected some portions of iron to be saturated and supersaturated with carbon, and to be fused into one mass together with other portions of ore not freed as yet from the whole of their oxygen: and this probably would have been the case even with charcoal as the fuel, but for the particular kind of ore employed. The essential ingredients of this are iron, manganese and carbonic acid. The latter is volatilised in the preparatory roasting and therefore needs no farther notice, we must therefore seek in the manganese for a cause to explain the appearances. It is stated, apparently on good authority, that it is not possible by any quantity of fuel to get grey pig iron from the manganesian carbonate of iron, and yet that a small alloy of manganese in iron greatly retards the escape of those lower proportions of carbon which make the difference between pure bar iron and common steel. This, if it could be clearly established, would be a great point gained in the formation of a true theory of the reduction of a very important class of iron ores; for it is not in Stiria alone that the manganesian carbonate of this metal is worked, but also at Schmalcalden in

Hessia, in the province of Biscay, in Piedmont Tyrol and France.

The comparative difficulty of reducing manganesian steel to iron is farther shown by the practice followed in some of the more recent Stirian forges. The metal being brought to a state of thin fusion is let out of the furnace into a cavity by the side of it and, when it has been quiet a few minutes, a thin crust of scoria rises to the surface. This is sprinkled with water which hardens it, and thus enables it to be readily removed. The clean surface of the metal now comes in sight and is consolidated by a second sprinkling of water; the rough plate thus formed being taken off, the process of sprinkling and taking off a second plate is performed, and so on till the remaining fluid mass is nearly in the state of steely iron. These plates are steel, and in order to purify them they are melted in a refinery blast furnace, the only precaution required for the preservation of their carbon being to avoid bringing the blast directly on them and lining with charcoal the crucible in which the melted metal is received. To convert the steel plates into iron, that is, to burn out their carbon, it is necessary to expose them to the action of the blast and to avoid lining the crucible with charcoal. Under these circumstances, apparently so favourable to it, oxidation goes on slowly, and the burning out the carbon is a tedious process. All practical writers maintain that a small alloy of manganese with iron is no detriment though it renders the iron somewhat hard, and Berzelius

analysed a good sample of iron, probably Swedish, in which he found 4 per cent. of that metal.

Among the more recent and correct analyses of manganesian iron ore that have been published by Klaproth I do not find any with a larger proportion of manganese than about 8 per cent., and in one of Descotil's analyses of the ore at Coalbrook Dale he notices 5 per cent. of manganese compared with the iron. By selecting those kinds of ironstone which contain manganese, and smelting them apart or mixed with the others in certain known proportions, results would probably be obtained, of great importance to the theory of the true method of working the argillaceous ores of iron, and equally so the pecuniary advantage of the iron-masters.



METALLURGICAL HISTORY OF IRON.—PART III.

AT our last meeting I described the Indian methods of obtaining malleable iron from the ores of that metal, and then proceeded to detail the reduction of the manganesian carbonate of iron as practised in Stiria and Carinthia. On the present occasion I propose to conclude the metallurgical history of bar iron by considering, first, the methods of preparing it in those works where the fuel employed in smelting the

ore and in the subsequent processes is charcoal; and, secondly, the processes in use in Great Britain where the fuel is fossil coal either in the state of coke or, as recently practised, is raw coal assisted by the hot blast.

At most of the smelting-works and forges on the continent of Europe charcoal is the fuel made use of; and the processes and manipulations are on the whole so similar, that the practice of any one country, and almost of any one establishment, might be cited as an example of the whole. I prefer however to take the details from the methods followed in Sweden and Norway, both because the best bar iron is made in those countries, and because in so doing I shall be able the better to avail myself of some facts and observations made by Berzelius and inserted in his Treatise on Chemistry.

At all the forges in the two above-mentioned countries in which the best iron is produced, the ore employed is the magnetic oxide which the Swedish smelters obtain from the mines of Dannemora and the Norwegian smelters from those of Arendal. At these places the ore occurs in large masses, so that much of it is got from open quarries without having recourse to more expensive methods of mining. We have no trust-worthy analysis of this ore, but we know that it consists for the most part of a mixture or combination of the magnetic oxide and peroxide of iron in the proportion of about 28 of the former to 72 of the latter. The extraneous metallic minerals that occur in it partially, and always in very small

proportion, are titanium, copper, zinc, chrome, and manganese.

About 300 years ago the purer and more fusible varieties of this ore were smelted in furnaces not more than about 3½ feet high, and then the process differed in no material respect from that at present in use in India which I have already described. The furnace was first filled with charcoal, and when it had thus become thoroughly heated, alternate charges of ore and of charcoal were poured in at the top of the furnace: the ore was unroasted but reduced to small fragments, and was mixed with limestone as a flux. The blast being set to work the charge subsided quickly from the rapid consumption of the fuel, so that the iron in each charge of ore when it had reached the focus of the blast was probably little if at all carbonised. As the mixture of melted slag and iron sunk below the action of the blast into the crucible (a bason of earth about 1½ foot deep) the particles of iron separated from the slag by their greater specific gravity and, in a pasty rather than fluid state, concreted into a spongy mass. This at certain intervals was drawn out, by tongs, glowing hot, and when sufficiently cooled was hammered, gently and cautiously at first, and then more powerfully, to press the particles of iron into contact and to squeeze out the intermixed slag. The rude mass thus obtained was cut up into smaller pieces each of which was repeatedly heated and forged till a sound bar of nearly pure iron was obtained. By degrees the size, and especially the height of the furnaces was increased, it

being found that a considerable saving was thus made both in the consumption of fuel and in the number of workmen employed; and the bellows instead of being worked by hand were moved by a water-wheel.

Somewhat more than 70 years ago M. Jars found the smelting furnaces of Sweden and Norway 30 feet high, from the tuyere hole to the base of the chimney: and it is interesting to observe how this change, adopted at first in all probability merely from motives of economy, modified the quality of the produce, and rendered necessary certain new processes in order to obtain in a malleable state the iron produced in these high furnaces.

The time taken by the ore to descend from the top of the furnace to the tuyere hole evidently depends on the space which it has to traverse in so doing; and in a descent of 30 feet during which the ore is surrounded by charcoal with a constantly increasing temperature, there is ample time for the iron not only to pass to the metallic state by loss of its oxygen but also to combine with from 3 to 5 or 6 per cent of carbon.

This compound is far more fusible than pure iron; and accordingly when the ore comes within the full action of the blast, not only the earthy impurities by help of the flux melt into a slag, but the iron likewise, in its now carbonized state, undergoes complete fusion. If the blast be stopped, it will be found that the melted metal takes a considerably longer time than under the former treatment to become solid, and also that when subjected, while still hot, to the most

cautious hammering, it breaks away into fragments being possessed of scarcely any tenacity. It was well known by the smelters that sulphur arsenic and other substances not only increase the fusibility of iron but also destroy its ductility; and, from a similarity of effect in the present case they inferred a similarity of cause; being also already in the habit of purifying copper and other metals from sulphur and various volatile substances by roasting them at a high heat, they were induced to submit this fusible iron to the same treatment. In the old process, the iron not being sufficiently fluid to run out, if a hole had been made for this purpose in the bottom of the furnace, there was a necessity of blowing out the furnace in order to allow of the mass of iron being removed; hence resulted a great loss not only of time but of heat; now however, all this inconvenience was avoided by piercing the bottom of the furnace from time to time and thus allowing both the melted metal and slag to run out, so that the smelting process could be carried on continuously for days and weeks together, till the furnace itself required repairs. The masses of iron thus obtained received an uniform size and figure from the moulds of sand into which the melted metal was allowed to flow and to consolidate.

One of these masses or pigs was then transferred to a furnace called the refinery, a low quadrangular stack of masonry with a sloping ledge inside just opposite to the tuyere hole. On this ledge the pig of iron was laid and was covered with slag and charcoal to pre-

vent the iron itself from burning away under the action of the blast: this latter was directed so as to strike chiefly on the under side of the projecting part of the pig, which was pushed forward from time to time in proportion as the end nearest the blast melted away. In about an hour's time the whole of the iron had run down into the crucible and, the blast being now suspended, it soon consolidated, and on being brought under the hammer was found to be more malleable than at first. A single roasting however was seldom found to answer the intended purpose; and therefore the mass when removed from the crucible was immediately replaced in the refinery, and the process above described was repeated once or twice according to circumstances, at the end of which time the iron was found sufficiently decarbonised and malleable to bear the hammer. Thus it happened that a mode of treatment, adopted from very loose and incorrect analogy and with the view of purifying the cast iron from substances that never existed in it, proved to be actually efficacious by separating the carbon, the real cause of the very imperfect malleability of iron in this state.

A modification of the refining process as above described has recently been adopted in Sweden, being evidently borrowed from the process of puddling which is an English invention. It is thus described by Berzelius. A pig of cast iron is placed in the refinery and treated in the usual way till it melts and runs into the crucible, but instead of being allowed to cool here and then submitting it to a second and third

fusion, its surface is covered with scoriæ and a man is employed with an iron bar in continually stirring and intermixing them. In a short time jets of flame arise from the surface of the melted metal, and soon after it becomes of a thicker consistence and at length is quite solid: being then taken out of the furnace and removed to the hammer it is found to have become just as malleable as it would have been by two or three fusions in the usual way. The scoriæ stirred into the melted metal consist of oxide of iron vitrified with silica and other earthy substances, all of which contain oxygen, which, reacting on the carbon of the cast iron, separates it in the state of an inflammable gas called carbonic oxide. This is Berzelius's explanation of the process, for he, differing in this respect from most other chemists, denies that cast iron contains any oxide of iron, founding his opinion on a very careful analysis made by himself of a specimen of cast iron which he found to consist of 91·63 iron; 4·57 manganese, and 3·9 carbon; the sum of these numbers making precisely the 100 parts originally operated on.

Thus, in the preparation of bar iron from charcoal pigs, if we assume as our groundwork Berzelius's analysis just cited, the whole of the process consists in burning out the superfluous carbon by directing the blast on the iron as it passes to a state of fusion, and the only precaution necessary is to perform this with the least possible loss of iron; a very considerable loss however actually occurs, the produce in bar from 100 of cast iron varying from about 77 to 80; of this deficiency however, a part is no doubt attributable to

the scales of oxide struck off the bars in the process of forging.

Of the method practised in the English forges, or Bloomeries as they were called, before the introduction of pit coal I cannot find any very distinct account. It appears however that only a single fusion in the finery furnace was given so as just to make the metal capable of bearing the hammer, the completion of the refining being effected by long continued forging.

The best and purest bar iron of Sweden is never entirely and absolutely pure, for it contains, according to Berzelius about $\frac{1}{2}$ per cent. of carbon and about $\frac{1}{10}$ of that quantity of silicium ($\frac{1}{2000}$), and bars both from Sweden and Norway not unfrequently occur containing so much carbon as to form with the iron an imperfect kind of steel. Such iron, when heated to a low redness and suddenly cooled, becomes very sensibly harder than before, just as steel does. Perfectly pure iron is a substance that many persons have never seen. It may be prepared, according to Berzelius, by mixing 4 parts of good bar iron with 1 part of black oxide, putting the mixture into a crucible, covering it with pulverised green glass, luting on a cover, and then exposing it for a proper time to a full white heat. The result will be a well fused button of a silvery white colour, very tenacious but sensibly softer than the original iron, and exhibiting a scaly conchoidal and sometimes crystallised fracture-surface. Such an iron would answer admirably well to be drawn into wire, but, for most of the other uses

to which this metal is applied, its softness would be a considerable objection. It is not therefore pure iron, but a kind possessing the required degree of hardness with as little diminution as possible of toughness and tenacity, which is demanded by the consumer and therefore should be the object aimed at by the manufacturer.

I now proceed to consider the processes employed to bring cast iron made with coke or coal to the state of bar.

It is evident that unless we know the composition of cast or pig iron, which is the material, and of bar iron, which is the result, and thus ascertain what substances they are which disappear or are separated during the process, we shall never be in possession of a satisfactory theory on the subject, or be able to apply a rational and consistent criticism to the modes of practise at present in use, or to suggest, except by vague analogy or from actual experiment, any improvements in this the most important of the metallurgical arts, and to which the prosperity of our own country is so deeply indebted. Unfortunately however in this part of our subject I have rather to note deficiencies inconsistencies and contradictions than sound and trustworthy facts. Some of these contradictions however may be reconciled, some facts hitherto not applied may be brought in illustration of doubtful points of theory, and if on the whole I should leave the subject clearer than I found it, my labour and your time will not have been spent in vain.

Next to the iron itself, there is the best evidence of

the existence of carbon in pig iron whether made with charcoal or coke; but considerable difference of opinion exists as to the quantity and state of this ingredient. The colour of the iron is usually considered as an indication of the proportion of carbon, the dark gray containing the most and the white the least. This however is not an unerring indication. M. Jars relates that he broke to pieces a common cast iron pot and filled two small crucibles with the fragments: he then luted a cover on each, put them into a small blast furnace and gave a heat sufficient to bring the metal into fusion. The contents of one crucible were then poured into a mould and formed a plate about two lines in thickness: the surface fixed in less than a minute, and when the plate had cooled it was broken with great ease and had all the appearance of ordinary white cast iron. The other crucible was covered up with hot charcoal and was eight hours before it had become cool; being then examined, the iron was found to be semi-malleable, difficult of fracture, and in colour of a dark gray almost black.

From these and other similar facts Berzelius is of opinion that, with the exception of the white iron produced by the reduction of those ores which contain manganese, and that which is occasioned by a deficiency of fuel, or which comes to the same thing, an excess of ore in the smelting furnace, all the other varieties of cast iron owe their colour solely to the circumstances under which they have consolidated. The iron as it runs from the furnace is therefore to be considered not as a single chemical compound but as a

mixture of several compounds, which when exposed suddenly to a temperature sufficiently cold to consolidate the most fusible of them, causes the whole to concrete into an uniform mixture, but which, by the action of a very gradually decreasing heat, allows each compound to separate from the rest in the inverse order of their fusibility, whence results a crystalline granular structure and a darker colour. As a natural consequence of this way of viewing the subject, Berzelius is inclined to consider the cementation of articles made of cast iron as only a mode of bringing about by slow cooling that increase of tenacity and commencement of malleability which unquestionably is imparted to quickly cooled gray cast iron by again heating and cooling it slowly. Some few years ago nails, knife-blades, locks and keys and other small articles were made of gray cast iron, and in this state were quite brittle, but by cementation with pulverised hæmatite or other varieties of oxide of iron were rendered in a considerable degree tough and malleable, in consequence, as was supposed, of having been deprived of their carbon by the action of the red hot oxide of iron in which they were imbedded for several hours. Berzelius states that this cannot be the reason because the same effects are produced by heating the articles in charcoal or even in sand.

These facts however may be admitted, and yet the inference in its full extent does by no means follow. It will readily be allowed that small articles of gray cast iron cooled quickly are in that state quite brittle, and yet by being kept at a full red heat for several

hours and then cooled slowly will become as tenacious as the original gray cast iron of which they were made, if the contact of air during this process is prevented, by imbedding them in sand or any other powder incapable of effecting any chemical action on the iron. But I have myself seen, and no doubt several now present have also seen, cast iron, nails after cementation in hæmatite so far deprived of their carbon and brought to the state of bar iron, as to admit of being drawn into wire and thus elongated to perhaps four or five times their original length, a property wholly incompatible with cast iron retaining its original dose of carbon. Mr. Mushet's experiments in which he fused Swedish bar iron with different proportions of charcoal, and noted the increase of weight thus gained by the metal, and its similarity to different varieties of cast iron in colour and texture in proportion to the quantity of carbon taken up by it, clearly show that iron combines with various proportions of carbon, and has its colour and texture correspondently modified, even when the heat to which the specimens were raised and the rate of their cooling were as nearly as possible the same. We may therefore I think safely adopt the opinion of the ironmasters, that the white the mottled and the gray varieties of cast metal indicate a successively increasing proportion of carbon, provided care has been taken to allow each kind a nearly equal length of time for its cooling. And this indeed is consistent with and justifies the practice of covering up most carefully with dry sand and coke dust those pigs of

gray cast iron which in a running are situated nearest the door of the smelting house, lest by cooling too quickly they should become lighter in colour and therefore apparently poorer in carbon than others of the same running and therefore of precisely the same quality. To determine accurately the proportion of carbon in the different qualities of cast iron is a very difficult problem. Berzelius as already quoted found in a specimen of manganesian cast iron 3·9 per cent. of carbon. Dr. Faraday found in gray pig iron, apparently saturated with carbon, as much as 5·64 per cent.: and according to Mr. Mushet, No. 3 iron contains 4 per cent. of carbon, No. 2 iron 5 per cent., and No. 1 iron 6·7 per cent.

Another inquiry respecting the composition of cast iron, interesting both in a theoretical and practical point of view, is whether it does or does not contain oxide of iron. It might be supposed that this question is capable of being determined *à priori* from the incompatibility of carbon and oxide of iron in the same substance at a high temperature, in consequence of the strong tendency of oxygen and carbon to combine together into a combustible or into an acid gas. But the liquid iron while in the furnace is pressed by the superincumbent weight of the scoriæ, and in such circumstances may be considered as a single compound, the mutual attraction of the elements of which may oppose its separation into other compounds. While flowing from the furnace it is subject only to the pressure of the atmosphere and is also in contact with the air, and now another series of attractions

becomes predominant. This is shown by the immediate separation of a quantity of nearly black spongy half crystallized scoriæ called kish which has never been analysed; and at the same time jets of flame burst from the whole surface, indicating in all probability the formation of carbonic oxide from the attraction, now become efficacious, of the oxygen and carbon two of the ingredients of the melted mass. The longer the iron remains liquid or even red hot the more of this inflammable gas separates, so that at length, in all probability, the whole of the oxide of iron would have been decomposed, its oxygen would have disappeared and with it so much of the carbon as was necessary for the conversion of it into carbonic oxide. In common cast iron however this is by no means the case, for Dr. Beddowes states, in a paper of his in the Philosophical Transactions, that when fragments of it were put into a retort and brought only to a low red heat, a continual disengagement of inflammable gas took place so long as the pressure on the contents of the retort exceeded only by a little the common atmospheric pressure, for he found that under a pressure of half an inch of mercury the formation of inflammable gas was wholly prevented. From these and other similar facts we may I think fairly conclude that the common cast iron, at least that made in this country, contains oxygen possibly and indeed probably in combination with an equivalent quantity of iron.

Let me now recall to your attention an analysis by Berzelius of manganesian cast iron (cited by me a little

while ago) in which he found absolutely no oxygen at all. It is well known that manganesian cast iron may be converted either into excellent malleable iron or into steel with far less trouble than the common varieties of cast iron can; the reason of this is evident if the specimen analysed by Berzelius be considered as a fair representative of this species of iron; for, its only ingredients being iron manganese and carbon, it is evident that by burning away only part of the carbon we obtain steel, and that by burning away the whole we get iron, a part of the manganese probably also separating in the state of oxide by the same process.

Another inquiry respecting the composition of cast iron is whether it contains any notable proportion of earthy matter, either in the state of earths or of their metallic or combustible bases. This question has been partly resolved by Berzelius, who states that cast iron always contains a little silicium and sometimes also magnesium. His experiments however were probably made on charcoal iron; and we want a good set of analyses of the different varieties of our own cast irons to enable us to answer this and many other very interesting questions in a satisfactory manner.

One of the causes of the inferiority of coke iron compared to that reduced by charcoal has been confidently stated to be the presence in the former of a notable quantity of sulphur, derived as is supposed from the coke employed in smelting the ore, and adhering to the iron through every stage of refining,

a smell of sulphuretted hydrogen being often perceived in plunging into water a bar of iron hot enough to decompose it. This latter fact may be admitted without at the same time admitting, on mere surmise, the existence of sulphur in cast iron, at least in the gray variety of it. If a bar of iron made white hot be rubbed with a roll of common sulphur, it is well known that the two substances will combine together into a very fusible compound which will fall down in drops. No such effect however is produced on gray cast iron: the sulphur will burn and evaporate from its surface without combining with it in the least degree. It is highly probable therefore that the minute quantity of sulphur observed not unfrequently in bar iron, is derived from the coal or coke used in forging the iron after it has been freed from its carbon by previous processes: and therefore that an objection strongly urged against the use of coal instead of coke in the smelting furnace, from the sulphur which it may contain, is perhaps without foundation.*

Another substance occurring in cast iron, and which materially affects the quality of such iron when made into bar is phosphorus. It is indeed chiefly found in those ores that go by the name of ochre and of bog

* Recent experiments seem to demonstrate the presence of sulphur in the lower qualities of *hot blast* iron. This is probably derived from the sulphur of the raw coals, which, being volatilized before the iron has become saturated with carbon, combines with part of the iron, converting it into sulphuret and thus rendering it insusceptible of combination with carbon.

ore, and which probably derive their phosphorus from the aquatic animals inhabitants of bogs and swamps the remains of which are mingled with the ore. Such ores though extensively worked in some parts of the European continent are not worked in this country. Its presence however may also be suspected in those varieties of common ironstone that abound in organic animal remains, and an evidence of the presence of phosphorus in bar iron of common quality may be derived from the peculiar smell (like garlic) which often characterizes the hydrogen produced by the action of dilute sulphuric acid on such iron. The effect of phosphorus in bar iron is to render it brittle when cold though it is perfectly malleable at a welding heat.

Such are the principal of those substances which occur mixed or combined with iron in the state of pig metal, and which in the subsequent processes of refining are more or less completely got rid of. What these processes are I now proceed to describe in the order in which they are performed, such as I had myself an opportunity of witnessing several years ago at a large smelting work in Shropshire, which at that time was producing some of the best iron in the English market. Some of these processes are omitted or modified in modern practice as I shall notice in their proper places.

The first is refining.

This is done by breaking the pigs into two or three pieces, placing them on a hearth, covering them with coke and slag, and letting on a blast till the metal is

melted; it is then discharged into a flat shallow iron trough and water is poured on that it may consolidate the sooner. The result of this is a thick plate called a slab. The metal in this state is very white compact excessively hard and perfectly brittle; a considerable quantity of black half crystallised heavy slag separates during the fusion; and some, but probably not much, of the combined carbon burns off: 31·74 cwt. of pig iron produce 26·45 cwt. of slabs or about 83 per cent.

Secondly—puddling.

Which was invented by Mr. H. Cort of Sheffield; and his patent for it is dated in 1784.

The intention of this process is to burn off the whole of the carbon and at the same time to separate nearly all that remains of intermixed slag. Several variations and improvements on the original mode of proceeding have been introduced; the practice that I have myself witnessed is as follows:

The furnace employed is a common reverberatory, the fuel is coal, and the slabs broken into pieces are heaped on the middle of the bed it being previously covered with sand. 3½ cwt. is a charge. The full force of the fire is let on for about half an hour, at the end of which time the metal being partly melted is broken down and spread by means of iron bars; in doing which water in small quantities at a time is thrown in. Each addition of water is instantly succeeded by much ebullition of the iron and the disengagement of jets of white flame. The spreading being completed, the door of the furnace was closed to pre-

vent the entrance of cold air and the flame was turned on for two or three minutes. The flame was then turned off again and the charge was worked by incessant stirring, water and a few wet scales of iron being occasionally added. This alternation of heating and then stirring and at the same time throwing water in, was continued till the metal began to lose its consistence and to break down into pieces like coarse gravel and afterwards to be comminuted like sand, copious jets of flame being discharged during the whole time. At length the particles began to clot together, and soon afterwards the whole mass acquired a pasty consistence and ceased to adhere to the tools; no more water was added, and the metal now began to burn with the white sparkling light of pure iron, quite different in appearance from the jets of white and bluish flame that characterized the former part of the process. The iron was now collected into five nearly equal lumps which were condensed by beating them while in the furnace with an iron mace, and were then dragged out of the furnace by tongs.

The rationale of the above process is very clear. The metallic oxide and carbon in the refined iron reacting on each other produce oxide of carbon, which escaping in the form of gas separates the particles of iron from each other, the cohesion of the mass being destroyed by the temperature to which it is exposed. If the oxide and carbon are duly proportioned, the addition of water would be injurious as increasing the quantity of oxide which would come away in the slag and thus occasion an unnecessary

loss of iron; and in Mr. Cort's specification there is no mention of water, nor was it used when Dr. Beddowes published in the Philosophical Transactions a very interesting account of the process as actually practised at that time. But where, as in the instance which I have described from my own experience, the refined iron contains little oxide and much carbon the addition of water greatly expedites the process, both by producing a quantity of oxide of iron, and by carrying off much of the carbon in the state of carburetted hydrogen: it may likewise be the means of separating small portions of sulphur, if such happen to exist in the slab iron, by combining with it into sulphuretted hydrogen gas.

The lumps or balls from the puddling furnace were then placed under a heavy hammer and stamped into thick irregular plates much scoria being squeezed out at the same time, the number of blows given to each lump being from 70 to 100. The plates were thrown while hot into water and being thus made considerably brittle were broken into pieces, which were then piled on one another to the height of about a foot and a half and were placed in a reverberatory furnace; each pile when glowing hot was then taken out by sticking a pointed bar into the top of it (the plates all adhering to one another by being at a welding heat) and was thus brought under the shingling hammer, by the action of which it was forged into a short thick bar called a bloom, now tough and malleable and exhibiting the usual properties of good bar iron. The 26·45 cwt. of slabs already mentioned produced 23·00 of

stamped iron, and this gave 20·00 of blooms. Hence 100 of cast iron yielded 63 of blooms. The blooms were afterwards heated by a charcoal fire and rolled into bars in the usual way, affording an iron which, for its combination of toughness and hardness, was at that time unrivalled.

The demand for cheap iron even though of inferior quality has occasioned the suppression of some of the processes above described and the modification of others. Sometimes the puddling process is wholly omitted; the iron as it comes hot from the refinery being stamped into plates which being piled in a reverberatory or *balling* furnace are shingled into blooms. Sometimes the only change is that the lumps from the puddling furnace are made into plates by passing them between rollers rather than hammering as being a cheaper though less effectual manipulation. Bar iron of British manufacture is now applied to such a multiplicity of purposes that its qualities are as various as the uses for which it is designed. For bolts nuts and such wrought iron work of steam engines as has to bear the greatest strain the best iron must be employed; and all persons agree in giving this highest place to the iron marked S C. made from pigs of Staffordshire iron by Messrs. Bradley Forster and Co. of Stourbridge. A bar of this iron may be bent cold without even cracking till the two parts are brought in contact; its fracture is mostly fibrous and its colour is white or very light gray. A mixture of hæmatite with the common argillaceous ore improves the toughness of common iron but is said to impair

its strength: such irons are usually characterised by a dark grey colour, and the best of them are in very high estimation being in tenacity equal to the best Staffordshire and inferior only in hardness. The common bar iron is often little better than cast iron, being hard but not unfrequently quite brittle: even in its best state if attempted to be bent cold it soon cracks, and then breaks short with a coarse granular fracture of a white colour.

A common defect in almost all sorts of bar iron arises from the process of *fagotting;* which consists in laying a number of short bars side by side and one on the other, taking care that the corresponding faces of each shall be in the same direction, then binding them together, bringing them up to a welding heat and drawing them down between rollers. The surfaces of these bars while heating, even of those that are in the middle of the fagots are exposed to the air and acquire a thin coating of black oxide. This oxide being infusible at a welding heat, the compression of the rollers has no tendency to bring it to the outside of the mass, so that it remains interposed between the bars now reduced to thin plates, thus effectually preventing their union in those parts where it occurs and forming the black lines visible in a transverse section of such iron. Indeed, if we observe a fracture of a bar of fagotted iron made by first nicking it and then gradually bending it while cold, we shall find it to consist of distinct laminæ or ribbons each representing one of the constituent bars of the original fagot, the uniform pressure of the rollers producing extension but

no incorporation of the bars such as is occasioned by a partial impulse like that of the hammer. Accordingly, if fagotted iron is softened in the fire and a blunt punch is placed at right angles to the layers and struck hard, it makes a well-formed hole; but if the punch be held parallel to the layers it makes an ill-shaped hole and causes the bar to open longitudinally by the separation of the laminæ of which it is composed.

X. ON ENGRAVING AND ETCHING.

From the German word Grüben or Graben, which means to dig or to mine, is derived the verb to engrave; and from the German word Aetzen, to eat, is derived the verb to etch. The essential idea of the first therefore is a hollow formed by the application of a cutting tool, and of the second a hollow formed by the action of eating corroding, or, to use the modern technical term, biting in.

All solid substances are capable of being engraved, but when the word is used as a term of fine art, it means the act of cutting out a representation of the form of any object on a surface of hard stone metal or wood. The art, in this its most extensive signification, dates from the highest antiquity — the engraved tables of the Jewish law, the sculptured gems set in the breastplate of their high priest, the cylinders of agate engraved with arrow-head characters that have been found in the ruins of Babylon, and the hieroglyphics sculptured on the temples and obelisks of Upper Egypt are examples which it is only necessary to name in order to prove the assertion.

It is not however my intention at present to enter

on the extensive and highly interesting subject of engraving in general, but to confine myself to that branch of it (comparatively of modern invention) which consists in cutting out figures on flat surfaces for the purpose of being printed from. But even this branch of the art is too extensive to be treated of in a single evening, since it includes all the modes of engraving on plates of copper steel and other metals as well as on wood. I must therefore still narrow my ground and restrict myself on the present occasion to engraving and etching on copper, excluding even mezzotint and aquatint, of which the former may be considered as a variety of engraving and the latter of etching.

I am induced to treat of engraving and etching together, because, although plates have been executed by engraving alone and still more frequently by etching alone, yet the almost universal practice at present is to apply both these methods in conjunction to the same work.

Engraving on flat metallic plates such as monumental brasses, and other similar works, had long been practised before it occurred to any one that copies of these works of art might be multiplied, by filling the incisions with ink and then transferring the impression to damp paper by laying it on the face of the plate and applying a suitable degree of pressure. Still more extraordinary is it that the art of printing playing cards from wood blocks should have been in full practice at Venice, considerably more than twenty years before that fortunate accident which, according to Vassari, gave to a Florentine engraver on silver the first hint

which was afterwards improved into the art of printing from engraved plates. It is true that an engraving on a wood block differs essentially from one made on a metal plate, in that the projecting parts of the former are those which receive the ink, the lights being mere spaces between them; whereas in the latter the incisions and hollows are the parts which receive the ink, the projecting parts being the lights; now, as these hollows cannot be filled with ink without the projecting parts being also covered, there is a necessity for wiping these parts clean before an impression can be taken. This however is so very simple an affair as scarcely to add any difficulty; and the hand-roller which was at first employed in giving the pressure to wood blocks would have been found equally efficacious when applied to metal plates.

Tomaso Finiguerra, the Florentine artist just alluded to, being employed in engraving a silver plate the lines and hollows in which were, according to the fashion of the time, to be filled up with a hard black varnish or enamel, was in the habit of occasionally dusting charcoal into the work in order to judge more accurately of its progress, and when the engraving was finished he poured melted sulphur over it in order to take an impression of it. It so happened that the charcoal dust was not entirely cleaned out of the lines, so that the prominent parts of the sulphur-cast were black and thus formed a striking contrast with the yellow colour of the rest. The attention of the artist being thus attracted to the circumstance, it struck him that by filling the lines with fine charcoal and pressing a

damp paper on them a more perfect representation of the work might be had than by means of sulphur. He tried the experiment, succeeded to his wish and communicated it to his townsman and brother artist Baccio Baldini about the year 1460. This latter carried the invention a step farther by engraving some simple designs on plates of brass, which he printed from, by holding the plate over a candle till the lines were charged with black, then wiping the ground clean and laying on the plate a damp paper to which he gave the necessary pressure by means of a roller. Some of these works coming to the notice of Andrea Montegna a Roman painter, and of a painter at Antwerp of the name of Martin, excited other persons both in Italy and Flanders to farther experiment, and thus the new art gained an independent establishment.

Printers' ink was soon substituted for mere lamp black, and copper for brass as the material of the plate; it being found that the former metal possessed greater softness toughness and soundness of texture than the latter. The rolling press was also substituted with much advantage for the hand roller.

These first steps having been made, the progress of the art for the next few years consisted chiefly in acquiring a more perfect command of the graver and of the few other tools employed, whereby the stiffness hardness and meagreness of the earliest attempts were corrected; larger works were also undertaken, and the importance of the invention was becoming more and more apparent, having been made the vehicle in

which the genius of Albert Durer delighted to exhibit itself, and in which Marco Antonio and his scholar Marco di Ravenna gave to the public, representations of many of the immortal works of Raffaello and of Julio Romano.

The next great advance was the discovery of etching; which seems to have been made about the year 1530. It consists in covering the plate with a wax or varnish, (technically called a *ground*,) impenetrable to acids, and in drawing on this wax lines and figures with the point of a needle, taking care to penetrate the varnish and to open the line quite down to the surface of the copper; an acid is then poured on which by eating or corroding the copper, wherever it has been exposed by the action of the needle, leaves on the metal a design similar to that drawn on the varnish. One advantage hereby gained was a saving of time, but a still greater consisted in the freedom and flexibility of the needle compared with the action of the graver, which peculiarly fitted it for the representation of foliage and the other elements of landscape as well as of some of the accessory parts in historical subjects. The use of the etching-needle is far more readily acquired than that of the graver, hence there exist many more mere etchings than mere engravings; and among these are several by painters, being copies from their own designs, executed with a spirit and vivacity seldom attained by professional engravers, and on this account interesting and valuable even when coarsely done.

In using the graver the progress of the work is

continually under the eye of the artist, and the depth and width of the lines that he cuts are completely under his command. It is by no means so with etching; the depth of the line depending on the state of the copper, the strength and temperature of the acid, and the time that it remains on the plate. Hence the old masters, even with all the help derived from stopping out, that is, covering with varnish such parts as were judged to be sufficiently corroded, often found on removing the wax that the acid had bitten too shallow or too deep. In the latter case the lines were rectified by the judicious use of the burnisher, but for the former the only remedy in their power was to cover the plate again with varnish and to re-enter or open each line laboriously with a needle or dry point, and then to strengthen them by a second application of acid. This difficulty continued to our own times, when it was removed by the discovery of the mode of rebiting; that is, of laying a second ground after the first has been taken away, so as to cover all the spaces between the lines of the first etching without filling the lines themselves: a plate therefore in this state may be again and again corroded, or bit, by acid in those very lines where it has already acted during the former bitings, and in consequence a degree of precision in etching is now attained wholly unknown before.

Another improvement of late date is mechanical engraving, consisting of the application of machines variously constructed for describing circles, ellipses of all kinds, and other mathematical curves, as well

as parallel and converging lines either straight or wavy. This variety of engraving owes its origin to the late Mr. Lowry; and Mr. Turrell, a pupil of Mr. Lowry, has extended its application by simplifying the apparatus expediting its action and enlarging its powers.

It would have been easy to fill up this slight sketch of the progress of the art of engraving by notices of the principal masters and of their works: but in so doing I should only have repeated the published observations of men far better acquainted with the subject than myself. I should also have encroached too much on the time, already short enough, required for entering into those details more appropriate to the practical nature of our Society, and which ought ever to be regarded as the main object of these meetings.

The material on which engravings are executed is copper plate. I shall therefore begin by considering what are the qualities of the copper or the circumstances connected with its manufacture into plates which are likely to affect the engraver. Somewhat probably depends on the purity of the copper. It appears from those books that I have had an opportunity of consulting, that the ancient engravers instead of purchasing their plates from the coppersmith ready prepared to begin on, were in the habit of polishing and burnishing their own plates, and from this circumstance acquired a more accurate knowledge of the qualities of their metal than can be possessed by artists of the present day. They always gave the

preference to the deepest coloured copper that they could procure, and such would necessarily be the purest, because the mixture of any other metal, even in very small proportion, dilutes the full red colour of pure copper with brownish or yellowish white. Swedish copper is the purest in the market, but of this none I apprehend ever finds its way into the hands of the engraver; I know however that the late Mr. Lowry was at one time in the habit of collecting the half-pence of one of the coinages of George II. for the purpose of being made into plates, on account of the extraordinary purity of the metal. Of the copper furnished by our own smelting works the least pure that I have examined contains not more than $\frac{3}{100}$ of alloy, and the best not more than $\frac{1}{100}$, of which the greater part is antimony and the remainder tin and arsenic. This alloy in the proportion of $\frac{1}{100}$ sensibly increases the hardness of the metal, which however in itself is I suppose no disadvantage: but the porousness occasionally found in plates, and which is a serious detriment to the engraver, is occasioned I suspect by the same cause. The melting points of arsenic tin and antimony are much lower in the scale than that of copper; when therefore the copper is fluid the other metals which it contains will have a strong tendency to assume the state of vapour; this will be opposed by the pressure of the surrounding fluid and by the chemical attraction which the metals have for each other, but, notwithstanding this counteraction, the upper part of a block of impure copper would be found to be of less specific gravity, that is,

more porous, than the lower part. Another disadvantage attending the presence of antimony and tin relates to the action of the acid in the process of biting in. This acid is the nitric, which, while it completely dissolves the copper, reduces the tin and antimony to a white powdery insoluble oxide which, collecting at the bottom of the lines, retards the corrosion downwards while it opposes less resistance to the lateral action of the acid. I should expect therefore that the biting on copper of this description would be shallower and wider than on purer copper.

Engravers' plates after being rolled out in the usual way between two iron cylinders are hammered. The good effects of this, as regards the artist, are that the metal is condensed, and pores or other flaws are thus in part obliterated. The hardness of the metal is also increased, which contributes to the advantage of the proprietor of the plate in enabling him to print off a greater number of impressions than a softer plate would afford. These benefits however are not obtained without some corresponding disadvantages; for, while at each blow the portion of metal actually under the hammer is condensed, that which immediately surrounds the depressed part is strained and extended: hence it happens that over hammering will break up and render rotten or granular the texture of the most malleable copper.

That this is not a mere hypothetical hazard will be rendered apparent when I state that etching machines are capable of drawing lines not more than $\frac{1}{500}$ of an inch apart, and even this thin barrier between two

adjacent lines is considerably diminished by the lateral corrosion of the acid: unless therefore the metal be very sound such lines would be liable to run together and destroy the evenness of the tint intended to be produced. Another evil of over hammering is that the action of the acid is thereby extremely retarded and the biting after all is very bad, being shallow wide and serrated at the edges. A remarkable proof of this occurred in a plate that passed through Mr. Turrell's hands. Part of the design had been etched and no fault was to be found with the biting; a tint was then ruled on, but the lines being thought rather too wide they were scraped out and the plate was then sent to the coppersmith to be knocked up, that is, to have the metal in the part which had been scraped hollow brought up by hammering on the under side to the general level of the plate. This was done, a tint was then ruled on and the acid was applied; the biting proceeded with extraordinary slowness, and after several hours and the successive use of acid stronger and stronger, till at length it was used almost undiluted, the lines were found to be shallow broad and ragged and the tint good for nothing.

With regard to the surface of the plate it must be perfectly smooth, free from scratches and accurately polished by means of the burnisher; the intention of which is that no part shall hold any ink except the lines put in by the artist. In order to prove the surface of a plate it should be inked and wiped, then covered with a sheet of damp paper and passed

through the press. If the paper comes out as clean as it went in, the plate is in a fit state; if any lines or dots appear on it, the scratches and pores, of which these are the impression, must be carefully closed by the burnisher.

The engraver begins his work on the plate by laying the ground. The essential qualities of the ground are that it shall adhere to the surface of the plate so as to prevent the etching acid from insinuating itself between the two; that it shall perfectly resist the corrosive action of the acid, and shall oppose no inconvenient resistance to the free motion of the graver or etching needle. These qualities are best secured by a composition of two parts of white wax, two parts of the resin called mastich and one part of asphaltum, melted together and afterwards kneaded into balls for use. The ancient masters employed a varnish more nearly resembling a japan; drying oil wax and resin were the chief ingredients of it, and, after laying it on, the plate was heated in order to drive off the volatile parts. What remained was a hard tough varnish capable of receiving an outline drawing of the design, and of supporting, that is of resisting in a certain degree the passage of, the etching needle, and thus giving to its traces a character of stiffness and formality resembling those of the graver which was considered at that time as an advantage. One great inconvenience however attended the use of this varnish, namely that it could only be removed by friction: charcoal was employed for this purpose, but with the hazard of scratching

and therefore injuring an etched plate by such treatment.

The mode at present employed in laying on the ground is, to make the plate somewhat hotter than can be borne by the hand, and then to rub it with a ball of the etching ground tied up in taffeta. The ball is passed parallel to the side of the plate forming bands the edges of which touch, till the whole surface is thus covered. The dabber, formed of a ball of cotton wool tied up in Persian silk, is then beat gently on the surface to equalise the varnish, care being taken to leave off before the plate gets cold, otherwise the ground will adhere to the dabber and be torn up from the surface of the plate. Especial care must be taken that no dust gets on the varnish during this process, for wherever it adheres and is not most accurately taken off again, there will probably be a flaw in the biting. While the plate is still warm it is to be held upside down, and a few pieces of wax taper twisted together are to be lighted and held below at such a distance as to smoke the ground but not to burn it.

The ground being thus laid, the next process is transferring to its surface the outline of the design. There are several ways of doing this.

Unless the original be a drawing made for the express use of the engraver, it must be copied of the same size as the intended engraving. This is done by dividing the original into a convenient number of squares by means of cross threads, and then dividing the paper which is to receive the copy into an equal

number of squares by a fine pointed pencil. The copy is then made in outline as accurately as possible, either by a black lead pencil or by a fine pen charged with red chalk ground up with some weak gum water. The cross lines or reticulations are then rubbed out, the drawing is laid between a few sheets of wet paper and when sufficiently damp is laid, face downward, on the copper and passed through the rolling press. By this means an impression sufficiently distinct, and in reverse, is transferred to the surface of the ground. If the original is a drawing in ink of the same size as the intended engraving although it will not give an impression by running it through the press as just described, a tracing may be made from the drawing in the following manner. The drawing is to be rubbed on the back with red chalk or plumbago (black lead) in fine powder, and is to be laid face upwards on the plate; being then secured at the corners with a little cement, the tracer of a pantograph properly weighted is passed over all the important lines in the drawing. The pressure of the point as it is carried along causes the coloured powder at the back of the drawing to adhere to the etching ground, producing a trace sufficiently distinct of every line that has thus been gone over. Sometimes, in order to preserve the drawing clean, the coloured powder is rubbed on a thin firm paper and the drawing being then laid flat on the clean side of it, they are both fixed by their corners to the plate and the tracing proceeds as I have described, only the pressure on the tracing point must be proportionally increased. With whatever

care however the tracing is made the drawing is more or less injured, and, besides, the design being transferred to the copper not in reverse, the prints will of course be reversed, which in many cases greatly injures their effect: this however may be avoided by making the drawing itself in reverse.

If the drawing is of the same size as the intended engraving but is too valuable to be treated as above described, a tracing is made of it in one of the two following ways. By first laying over the drawing a thin paper rendered semi-transparent by oil or varnish, and then with a fine pointed pencil making as accurate an outline tracing as possible; this is then to be laid reversed, that is face downwards, on the plate, and the action of the rolling press will transfer a print of it to the surface of the etching ground.

But by far the best method of tracing is by the use of glass paper. This substance, so called from its perfect transparency, appears to be a film of dried isinglass jelly. It is laid over the drawing, and a tracing is made on it by means of a sharp pointed needle, a little finely powdered black lead being then gently rubbed on it, fills up the scratches made by the needle, and is prevented from adhering to any other part by the exquisite polish of the unbroken surface; the tracing is then, without being damped, laid face downwards on the copper, and transfers an impression to the ground by means of the rolling press.

The outline being placed on the etching ground by some one of the methods just described, every line is to be cut down through the ground by means of the

etching needle, the point of which is finer or thicker according to the strength of the lines that are to be drawn. The extreme thinness of the ground prevents it from offering any obstruction to the free passage of the needle, the only resistance being made by the copper, which according to the general practice is slightly scratched. Some of the ancient engravers however used a round pointed needle expressly to avoid cutting the copper, preferring rather the risk of indenting it. Their reason probably was that a sharp needle cannot scratch the copper without throwing up a bur on each side just as a graver does: this bur raises up the ground also and thus contributes to give a serrated edge to the line when bit in. Another reason for not scratching the copper is, that the needle obeys more freely and easily the impulse given to it by the artist while merely gliding over or indenting the metal than when tearing it up. All the lines having been thus opened by the needle a border of wax about an inch high is raised round the margin of the plate, which is now ready for the etching properly speaking, or *biting in*.

Some liquid acid must be employed for this purpose capable of fulfilling the following conditions, that it shall corrode and dissolve copper at the common temperature, that the salt of copper thus produced shall be very soluble in the acid, and that it shall give some visible indication of the rate of its action. The acids used by the old engravers, especially on hard ground, were very compound, containing some useless and some injurious ingredients; the only effi-

cacious ones being aquafortis and acetic acid. The plate was set in a sloping position over a trough, and the acid was poured by a spoon on the upper part whence it flowed down over the whole surface of the plate into the trough: this was continued from one to three or four hours and the progress of the biting was judged of from the green colour of the plate, that is from the verdigris which had collected in the lines. At present the only acid employed is the nitric properly diluted with water. The common aquafortis or nitrous acid of the shops contains, besides other impurities, muriatic acid, oxide of iron, and sometimes sulphuric acid. The experience of those engravers who have actually made comparative trials seems to be decidedly in favour of nitric acid as pure as possible. There are three tests easily applicable by which the presence of the above mentioned impurities may be ascertained. Absence of colour after the acid has been boiled for a few minutes in a glass flask indicates purity from iron, as a yellow or orange colour after boiling indicates the presence of that metal. A drop or two of nitrate of silver will give a white precipitate changing to lilac by exposure to light, if muriatic acid is present, and sulphuric acid is indicated by a white precipitate with a solution of nitrate of barytes, a small portion of the acid having previously been diluted for this purpose with six times its bulk of distilled water.

As soon as the acid begins to act on the copper small bubbles are seen to rise from the bottom of each line; they quickly increase in size, and if left to them-

selves would burst and be succeeded by others; the rate at which the bubbles form and increase, and the rapidity of their succession, indicate the activity of the acid and the progress of the biting. While this is going on, the artist is continually sweeping the surface of his plate with the feather end of a pen or with a brush in order to clear off the bubbles and thus ensure evenness in the biting, as well as to break off the ground in proportion as it gets undermined by the action of the acid on the sides of the lines. If this is not duly attended to, the bubbles will collect under the ground as the copper is removed, and at length by their buoyancy will blow it up irregularly and thus produce lines with ragged edges. Each line being presumed to be equally exposed to the action of the acid the whole will be bitten to an equal depth, and would therefore when printed be of an equal colour, for the colour depends on the quantity of ink that the etched lines will receive and deliver to the paper.

The lights and shades in etching are produced by the process of *stopping out*, which is thus effected. When the acid has acted long enough on the plate to produce the lightest colour required in the print, it is poured off; the plate is well washed with cold water and is dried by laying over it cuttings of fine unsized paper. Those lines that require it are then re-entered with the needle, and the parts that are sufficiently bitten are covered with a solution of asphaltum in oil of turpentine applied by a brush. They are thus stopped out, that is are protected from the farther action of the acid. When the stopping out varnish is

dry, the acid is again poured on the plate, where it remains till a farther corrosion, equivalent to the second degree of colour, has taken place; the acid is a second time poured off and the plate is washed and dried and stopped out as before; and this process is repeated till the great masses and degrees of colour have been obtained. The walling wax is now taken off, the ground is softened and broken up by washing it with oil of turpentine, and the plate after being thoroughly cleaned by caustic potash is ready for the second series of operations.—These consist, in the first place, in drawing out to a fine point the blunt terminations which etched lines necessarily have: this is done by a tool scarcely differing from the etching-needle and called the dry point, because the lines which it makes are cut into the copper and do not require the subsequent action of acid: it is therefore a species of engraving and the bur raised by it must be removed by the scraper. But by far the most important process is rebiting. It was invented about thirty or forty years ago by Mr. Walker an engraver of some celebrity, and has subsequently received some modifications and improvements chiefly from Mr. J. Lekeux. The etched plate being well cleaned is rubbed over with a rag dipped in a dilute solution of caustic potash, and is then gently warmed till the moisture is driven off: the surface of the plate is then rubbed clean with a damp rag taking care to leave as much alkali as possible in the lines. The rebiting ground is then laid with common etching wax, but with a light and delicate hand avoiding as much as

possible to cover the lines. The acid is then poured on; and the effervescence which it immediately occasions with the alkali cleans out completely the lines already etched and exposes them afresh to the action of the acid. The rebiting ground is never smoked, for that would not only be useless but would be injurious in clogging the lines with lamp black; hence the rebiting varnish is transparent when laid on of the proper thinness, and to a common observer would appear only as a slight stain. By the judicious use of this process combined with the dry point, the rawness of the first etching is corrected and the most perfect gradations and blending of light and shade and colour are produced.

In making right lines the etching needle used to be drawn along the edge of a common ruler; subsequently, a parallel ruler was employed: that now before you was made under the direction of Mr. Turrell; its joints are cones which prevent them from becoming loose or shaky by wear.

Ruling machines of various construction have for some years been coming into general use; by these the spaces in a series of lines may be drawn rigorously equal, or may be made to enlarge or contract according to any given proportion; converging and diverging lines may also be drawn as well as circles or ellipses. The cutter by which these lines are formed is a point of diamond.

Machine etching is chiefly employed in landscapes, for the blue expanse of the sky; and in portraits, for the back grounds: for foliage and other rough and

irregular or fantastic parts the etching needle is well fitted, but for faces figures clothing and everything that is best expressed by a firm smooth definite line there is nothing equal to the graver.

This is a cutting tool, the point being usually lozenge-shaped; and being pushed forwards by the hand ploughs a furrow, shallow at first but by repetition of the action acquiring any breadth or depth that may be required. The manipulation or mode of wielding both this and the other tools employed by the engraver cannot be described in words, and if such were possible, it would only be taking up your time with minutiæ which however important have only a professional value.

The last point that I shall mention is the mode of correcting a plate by what is called knocking up. The defective part is cut out by a scraper or scorper, taking care to slope the sides of the cavity in a considerable degree; the situation of the part opposite to it on the back of the plate is found by a pair of callipers; the plate is laid face downward on a smooth anvil, being pressed down with some force, a punch of steel is then applied to the part marked by the callipers and is hammered till the hollow is brought up to a level with the rest of the face; finally, it is burnished with a piece of charcoal and oil.

If I have succeeded in giving you a correct general idea of the art of engraving on copper plate, you will perceive that it includes a great variety of processes, partly chemical but chiefly mechanical, and depending for their success on certain niceties or dexterities of

manipulation. The effect however, or thing produced, is an object of fine art, a representation of select or ornamented nature which addresses itself to our affections our imagination our principles of taste. But these feelings can never be vividly excited unless the artist holds steadily in view the great object, keeping all the other departments severely subordinate to it, merely as means concurring to produce the end. Hence the fewer hands a work of art passes through to its completion the better, for no human hand can be employed in any work (except that of uniform mechanical routine) without leaving on it the impress of the intellect by which that hand was directed. On comparing the etchings or engravings by painters of their own works with the elaborate engravings of the present day, it will I think be felt that in the former the high and ultimate object of fine art is far more predominant than in the latter; I say predominant because the means employed to produce this effect are just sufficient and no more; for though, as such, these means may be fair and useful objects of criticism or admiration to the professional engraver, they are nothing in the eye of him to whom a painting or engraving is only a mode of exciting mental emotions. For the same reason the portraits by Holloway and Sharp are to my feelings more agreeable than some more modern and more highly finished works; for, although it is impossible not to be struck with the style of execution that characterises these two masters of their art, there is an ease and simplicity in their performances which allows the mind to

return without difficulty to the contemplation of the main object of their skill the expression of character and intellect. The multitudes of book plates lately produced, finished with microscopical precision, have I think injured the public taste by occasioning a demand for larger prints in the same style of laborious littleness. No single piece of this kind can be executed by any individual artist, both on account of the labour and the perfection required in each species of work that enters into the composition of a modern plate; and although by the union of two or more artists, each supreme in his own department, a plate may be filled with work so as justly to be entitled to rank as a miracle of art, the want will still be felt of a master-mind strong enough to crush together these concurring rivalships into an harmonious and due subordination to the highest excellence in art, expression.

XI. ON PAPER.

The art of writing, by means of which tradition, vague fluctuating and perishable, has been converted into recorded and progressive knowledge, is the great instrument whereby the civilization of the human race has been effected. It is therefore a subject both of liberal curiosity and of practical utility to examine into the comparative fitness of the various substances that have been employed to receive and perpetuate written characters. In early times, laws civil and religious, inscriptions commemorative of the illustrious dead, and, perhaps, astronomical observations for the division of time and the appointment of festivals, would be the chief things requiring record; and, as long-enduring and uncorrupted transmission would be the object aimed at on all these occasions, it is quite natural that the hardest and most unalterable substances, such as stone and bronze, should be chosen for this purpose. The Mosaic law was originally inscribed on slabs of stone: the private and constitutional law both of the Athenian and Roman republics, was engraved on twelve tablets of bronze.

As the occasions of written record both for private

and public purposes became multiplied, the weight and bulk and general cumberousness of stone and metal, as well as the slowness of the process of engraving on them, stimulated invention to discover more portable and commodious materials. These were chiefly sought for and found in the vegetable kingdom, although among wandering and pastoral tribes the prepared skins of animals and sometimes even their bones, especially the shoulder-blade, were had recourse to.

Of vegetable substances, the first chosen would doubtless be those which nature presents in a state fit for immediate use; such are all those kinds of leaves which, with a sufficient size, possess also a certain firmness of texture to enable them to bear the action of the style or other sharp-pointed instrument by which the forms of the letters or characters are traced. The prophetic leaves of the Cumæan sibyl are familiar to every schoolboy; and the oaks of Dodona hung with oracular leaves, express in the language of the poets the same primitive custom of inscribing on leaves the responses given to those who came to consult this venerated shrine of ancient Greece. In many parts of tropical Asia the leaves of various kinds of palm trees have been used from the remotest antiquity to the present time as the common material for writing on. They are cut into rectangular slips two or three inches wide and a foot or more in length, and, being bored near each end, are strung on two cords and thus formed into books. The use of leaves for this purpose in Europe has for

many ages past away, but perhaps a record of this old custom may still be found in the word *leaf* which even now we apply to the sheets of paper when sewed up into the form of a book.

Another ready-made material for writing on has been found in the bark of certain trees. The flexible innermost bark of almost all trees is sufficiently smooth and compact for this purpose, and may readily by compression be flattened into a thin layer. The outer bark was called by the Romans cortex, the inner bark *liber*, and this latter word being in the Latin tongue the most common name of a book, would of itself, independently of direct historical testimony, be a proof of its extensive use in ancient Italy for the purpose already mentioned. It hardly need be pointed out that hence are derived our own terms, *library*, *librarian*, &c.*

Of many of our forest trees, such as the oak and the elm, the outer bark, as they advance in growth, becomes spongy and deeply furrowed by longitudinal cracks and is cast off imperceptibly and only by small portions. A few trees, such as the American and Oriental planes, cast off every year the outer dead layers of their bark in broad flakes, which, no doubt, in want of better materials might conveniently enough receive written characters. Other trees, such as the lime the sycamore and the beech, always pre-

* *Libel* (*libellus*) in its original meaning is a *little book*; and in the time of Elizabeth and James the First bore only this sense, which it still preserves, as a term of civil law, both in England and in Scotland.

sent a smooth exterior bark, the layers of which from their great condensation cannot be readily separated from one another; but the entire covering of the wood, when stripped off and flattened by being dried under pressure, forms tablets not ill adapted for writing on. The word which we pronounce beech was called by our Teutonic ancestors *bock*, and still retains nearly the same sound in the dialects of Germany Holland Denmark and Norway: hence is derived the English word *book* which therefore has a near analogy with the Latin word liber.

The Egyptians, whose origin is lost in the night of antiquity, but who were certainly a highly civilized agricultural people when the ancestors of the Jewish nation were wandering shepherds on the skirts of Palestine and of the great Assyrian deserts.—The Egyptians inhabited a country little favourable to the growth of trees, and in consequence do not appear to have ever made use of bark for writing on. This may perhaps be the reason why the number of their obelisks and of other inscribed monuments of stone so greatly surpasses all other similar memorials that are to be found elsewhere. But, beside these, their ingenuity discovered a resource in a rushy aquatic plant that abounded in the immense marshes and stagnant pools of shallow water which anciently occupied a large part of the surface of lower Egypt. This plant, mentioned by Herodotus and Homer under the name of βίϐλος (*biblos*), has a woody matted root two feet or more in thickness, from which arises a tuft of sim-

ple narrow sharp-pointed leaves: from among these push up a few upright triangular stems from ten to fourteen feet high, crowned by a nodding tassel of green filaments at the base of which are the chaffy rush-like flowers. These stems are tough, like those of the large water-rush of this country of which the bottoms of chairs are made, and in the time of Herodotus were twisted into cables for ships and were also made into matting of which were formed the sails of vessels navigating the Nile. This same plant is described by Theophrastus, a contemporary with Aristotle and with Alexander, under the name of πάπυρος (*papuros*); he mentions its use for matting and sails and cordage, and adds that the most remarkable use of it is for books.* The name which Theophrastus gives to this plant is, no doubt, its native Egyptian one with a Greek termination superadded, and perhaps has some connexion with Papremis the name of a city and district on the African side of the Delta. The Latin *papyrus* and our own *paper* are obviously the same word, in the latter case probably hardly at all changed.

M. Varro as quoted by Pliny (Hist. Nat. xiii. 21) considers the use of papyrus as a material for writing on to have commenced soon after the foundation of Alexandria: and if we assume this date as correct, it enables us to assign an antiquity not greater than that

* The Greek word for book is βιβλίον (*biblion*), which under the form bible, *the book*, has been adopted into our own language.

of Alexander to the oldest of those mummies in the cases of which have been found rolls of papyrus.

If we cut a stem of papyrus across we shall find that the exterior green bark, which is very thin, incloses a white cellular pith containing a few longitudinal woody fibres; a texture, one would think, as ill adapted to be written on as could well be chosen among all the varieties of vegetable organization; and in truth the paper made of this substance had always great defects, though for some centuries it was almost the only article employed for this use in the Roman empire. The rolls of manuscripts found at Herculaneum appear to be all of papyrus, and from Pliny and other classical writers it is clear that the manufacture of paper was one of the most important of those carried on in Egypt and at Rome. The following was the process. The fresh stem being cut into pieces about a foot or a little more in length was stripped of its bark, which, as I know from experiment on a stem of papyrus grown in a stove in England, peels off very easily. The pith was then cut down longitudinally into sometimes fewer but never more than twenty slices: of these the middle ones as being the widest were reserved for the best paper, and the others were formed into three or four sorts according to their width. A table was wetted with the muddy glutinous water of the Nile and a row of slices was laid down on it, each slice touching, probably a little overlapping, the adjacent ones. This first layer was then crossed by a second one of inferior quality, and the leaf thus formed was put under a

press in order to consolidate and unite all the parts; finally it was dried in the sunshine. As the papyrus could not be sliced except when fresh cut, the Roman paper makers, of whom one Fannius in the reign of Augustus was the most celebrated, confined their attention to the remanufacture of the paper as imported from Alexandria.* Paper of the 4th quality (called amphitheatrica) was preferred for this purpose. It was in the first place entirely taken to pieces and then put together again with a looser texture, flour paste with a little vinegar being the cement most generally employed, but for the very finest sort boiling water was poured on crumb of bread and strained from it when cold. The leaf was then beaten carefully with a mallet in order to extend all the slices evenly and to bring them in contact, it was then a second time brushed over with size, and a second time beaten, after which it was pressed and dried: lastly, it was polished by rubbing with a dog's tooth or smooth shell.

The paper thus remanufactured obtained the highest price in the market,† but Pliny very justly observes respecting this highly glazed paper, that being

* As a proof of the great importance of the manufacture of paper in Egypt about 300 years after the reign of Augustus, it may be mentioned that when one Firmus raised the standard of revolt in Egypt against the Emperor Aurelian, he boasted that he would maintain an army from the sole profits of his paper trade.—Gibbon ii. 374.

† The best paper from the Fannian manufactory was about ten fingers breadth wide: but in the reign of Claudius the size of the sheets had increased to a foot and even to a foot and a half.

thus rendered less absorbent of ink the characters written on it were less durable, which will at once be understood by bearing in mind that the ink used in the time of Pliny was only lamp black or finely ground charcoal rubbed up with gum-water. Six qualities of writing paper were distinguished, besides the charta emporetica, wrapping or shop paper, which was made of the refuse of the other kinds, and a farther supply of paper for the latter purpose was derived from the works of unpopular authors; the satirists and epigrammatists of the Augustan age without ceremony dooming their literary rivals to that last refuge of unreadable works.*

The most ancient form of books appears to have been the *volumen* or roll, from which our word *volume* is derived, but from the time of the Emperor Tiberius books were often made up in flat leaves or *paginæ*, whence we have got our own word *page*.

From the want of fibre in papyrus paper it requires very tender usage to prevent it from being speedily worn out; we know however, by the rolls found in the mummy cases, and by those that are carefully preserved from use in the cabinets of the curious, that it will endure the mere effect of time for many centuries. Pliny mentions that he had seen in the library of Pomponius Secundus autographs on papyrus of Caius and of Tiberius Gracchus that had been written 200

* Ne nigram cito raptus in culinam
Cordyllas madidâ tegas papyro,
Vel thuris piperisque sis cucullus.
MARTIAL, iii. 2.

years before; he also says that he has frequently seen autographs of the Emperor Augustus of Cicero and of Virgil; but these were probably not more than 70 or 80 years old. At one time in the reign of Tiberius there happened such a scarcity of paper, from causes that are not mentioned, that the Senate in order to prevent a riot were obliged to appoint commissioners to distribute paper to the applicants according to their respective demands.

In the 6th century the manufacture of Egyptian paper continued very flourishing notwithstanding it was loaded with the payment of heavy taxes; but this circumstance and the cost of the manufacture itself, induced, in Gaul Germany and the other provinces of the Roman empire the most remote from the Mediterranean, the use of bark-paper and dressed skins of sheep and goats as a substitute for it. In the 7th century paper made from cotton-wool (χάρτη βόμβυκινη) began to be introduced into Constantinople and other cities of the eastern empire: and the Egyptian paper, being incapable of bearing a competition with it, as the new paper was both cheaper and better, began soon after to decline. It continued to be used in Italy longer than in any other part of Europe, but seems to have been silently and gradually discontinued in the 11th century. With the introduction of cotton paper we arrive at a very remarkable era in the art of paper-making, namely its manufacture from fibrous vegetable substances by first beating them in water and thus breaking down their original or natural texture into a kind of pulp, and then recon-

solidating this pulp into thin pliable leaves of an uniform consistence. It is worth while to endeavour to trace this very ingenious process to its origin.

Casiri in his Bibliotheca Arabico-Hispana states that paper was first brought to Mecca in the year 88 of the Hegira — 710 A.D. This date corresponds with the first conquest of Samarkand by the Arabian Mahomedans or Saracens; and the same author informs us that about 60 years before this event paper had begun to be imported from China to Samarkand,* which at that time was the great staple for Chinese commodities, whence they were dispersed by the usual commercial routes through the western parts of Asia and even as far as the markets of Constantinople.

The earliest existing specimens of paper are supposed to be in the library of the Escurial; for these however the highest antiquity claimed is the 11th century, and in all probability the paper is of Spanish manufacture. We are therefore totally ignorant of the materials employed by the Chinese in the paper made by them at the time of its first introduction to Europe. The paper made in Persia, in Arabia, in the eastern and western empires in imitation of the Chinese papers, was undoubtedly prepared from cotton wool chiefly, and in Arabia also from cotton rag; but I think there is good reason for suspecting that cot-

* For many centuries Samarkand continued to furnish paper of the best quality. "The best paper in the world comes from Samarkand."—Memoir of Sultan Baber by himself: he conuqered Samarkand in 1497.

ton never entered into the composition of Chinese paper.

There is a small tree called the paper mulberry (Morus papyrifera) which grows wild in the southern provinces of China, in Ava, in the Burmese country, and in India, as well as in all the Asiatic and Polynesian islands from Japan to Otaheite. The bark of this tree is remarkable for its fine texture of obliquely crossing fibres unmixed with any other substance, except a little mucilage, by means of which and the peculiar arrangement of the fibres a bark of the ordinary density is compacted. If a strip of this bark after being soaked in water is laid on a smooth stone, and carefully beaten with a bat the surface of which is cut into fine ribs, the fibres will separate more or less from one another; and if the beating is continued long enough, but not too long, the bark assumes the appearance of a web of fine linen. Two pieces of bark may be made to incorporate with one another by laying them so as to overlap a little and then beating them. In this simple way is formed the substance commonly called bark-cloth. By a short exposure, when wet, to the sunshine it becomes perfectly white, and may then be dyed or printed in the manner of linen or calico. The inhabitants of many of the Indian islands dress entirely in this cloth, and the people of the Sandwich Islands are particularly skilful in its manufacture. In the more civilized islands, such as Java and Sumatra, bark-cloth is less used as an article of clothing but is the common material for

writing on. For this purpose it is less extended by beating than the cloth, so that it is stiffer and more solid, and is also polished by rubbing it with a shell or other substance. In this state it has much the appearance of parchment, and bears ink perfectly well, as the Javanese book from the library of the East India Company, which I am allowed to exhibit to you, clearly shows.

If the beating is continued a sufficient length of time, the fibres are torn and separated from one another so as to form a kind of stringy pulp, which when poured into a sieve forms a thin even layer after the water has filtered away from it, which is the basis of manufactured paper.

Much of the paper made in China is of this material: the green shoots of the bamboo also contain a considerable quantity of fibre which is applied to the same purpose. The silky lustre characteristic of certain varieties of Chinese paper has induced some writers to state that silk is also an ingredient. This however I have no doubt is a mistake. The most silky looking Chinese paper that I have met with is decidedly wholly vegetable, for it burns without any of that frizzling and that peculiar odour which characterize the combustion of animal fibre, as every one knows who has burnt a feather. I am inclined to think that no other substances, except the two that I have mentioned, are employed in China as a material of paper. In many of the coarser kinds from that country one or other of these substances may very satisfactorily be detected, and the finer whiter and

more compact kinds have at least nothing of the spongy woolliness that characterizes cotton paper.

All that has been published respecting the manufacture of paper in China amounts to a very general description, which may be told in a few words; but on examining an extensive collection of Chinese paper which the Society of Arts, &c. possesses through the liberality of one of their members, J. Reeves, Esq. of Canton, there are many varieties which, from the length of the fibres of which they are composed and the general arrangement of those fibres in one direction, it would be very difficult to manage by any known European method.

The first process is the separation of the mulberry bark or the bamboo into its constituent fibres. This is done sometimes by putting the material into a large mortar then wetting it and afterwards pounding it by hand till the object is accomplished, or more commonly by submitting it to the action of stampers raised in the usual way by means of cogs or cams fixed on a revolving axis.

This process is seldom so effectually accomplished in China as in England, in consequence partly of the inferiority in the power applied, and partly no doubt from the greater length of the fibres and from working on raw materials instead of on old half worn rags.

The bark being now brought to the state of pulp or paper-stuff, the next process must be the bleaching; but how this is effected I have not been able to learn: much of the Chinese paper has a yellowish brown

colour, which I presume is natural to it, and the mulberry bark, after being continually washed during the beating, becomes so nearly white as to be easily bleached by subsequent exposure while wet to the sunshine, in the manner practised by the people of Otaheite and of the Sandwich Islands.

The paper-stuff being mixed with water, or, as some say, with water in which rice has been boiled, is brought to the state of pulp and is then transferred to a vat, having on each side of it a drying stove in the form of the ridge of a house; that is, consisting of two sloping sides touching at top. These sides are covered externally with an exceedingly smooth coating of stucco, and a flue passes through the brick-work so as to keep the whole of each side equally and moderately warm. A vat and a stove are placed alternately in the manufactory, so that there are two sides of two different stoves adjacent to each vat. The workman dips his mould (which consists of a sieve-like bottom and a moveable raised frame surrounding it) into the vat and then raises it out again: the water runs off through the perforations in the bottom, and the pulpy paper-stuff remains on its surface; the frame is then removed, and the bottom is pressed against the side of one of the stoves so as to make the sheet of paper adhere to its surface and allow the sieve to be withdrawn. The water speedily evaporates by the warmth of the stove, and before the paper is quite dry it is brushed over on its outer surface with a size made of rice; this also soon dries and the paper is then stripped off in a finished state, having one surface exqui-

sitely smooth, it being the practice of the Chinese to write only on one side of the paper. While this is taking place the moulder has made another sheet and pressed it against the side of the other stove, where it undergoes the operation of sizing and drying as the other had done. If sheets of very large dimensions are to be made, the mould is suspended by a tackle and is managed by two men, but in other respects the process is the same as that just described. Exceedingly beautiful paper is produced by this very simple and efficacious method, as the various specimens on the table abundantly prove. Paper is made in India in much the same way and with nearly the same materials; but in the provinces north of the Ganges and in Nipal, the common material is the bark of a species of Daphne which, like that of the paper mulberry, consists almost wholly of fibre, specimens of which in its raw and manufactured state were sent to the Society a few years ago by Dr. Wallich and the Marchioness of Hastings. This paper has a certain degree of acrimony which prevents the white ants from eating it, an invaluable property in India where all records on common paper are so soon destroyed. Paper-stuff unmanufactured forms an article of export from China to some of the neighbouring countries.

In Cashmeer it is mixed with some other ingredient, apparently cotton, and forms a paper with somewhat of the lustre of damask; the specimens of which now before you were obtained in that country by Colonel Moorcroft, and were deposited by him in the museum of the East India Company.

The use of cotton paper in Europe continued from the 8th to the beginning of the 14th century.* At this time, certainly as early as 1308, paper began to be made of linen rags. A good deal of obscurity hangs over the origin of this manufacture; we neither know the name of the inventor nor the country in which it was first made; there seems reason however to believe that it originated with some Greeks who had settled near Basil in Switzerland. The great superiority of linen over cotton paper occasioned it at first to go by the name of Greek vellum; the preparation of cotton paper was soon discontinued; and, when the appointed time had arrived, about a century afterwards, for the discovery of printing, there had been already established in most countries of Europe manufactories of beautiful linen paper ready to give currency to the productions of that great reformer and civilizer the printing-press.

The following is a general description of the present mode of manufacturing paper.

The materials are linen and cotton rags of all sorts, white and coloured, also old canvas, ropes and yarn, but no raw material. They are collected from all quarters packed into large bags and are sold by the rag-merchants to the manufacturer. The bags being opened the rags are first put into the dusting engine,

* But Pierre Maurice, surnamed the Venerable, a contemporary with St. Bernard, and who died in 1153, speaks, in his treatise against the Jews, of paper made of old rags " ex rasuris veterum pannorum," and those were probably linen rags.—Arts et Metiers, iv. p. 407.

which is a hollow cylindrical frame covered with wire net: to this a rapid rotatory motion is given, and thus all sand and loosely adhering dust and dirt are separated.

The next operation is sorting; and on the accuracy of this much of the success of the subsequent processes depends. All the blue rags are thrown together, as also are the cotton rags and the linen ones both white and of all colours except blue. A second examination now takes place; all seams are cut open with a sharp knife, and the rags of each parcel are arranged according to their respective strength, that is, according to the time and labour required to bring them to the state of pulp. It is evident that, if this sorting did not take place, the paper would be blemished by threads and half reduced rags, or, if the process of beating and cutting had been continued long enough to reduce the strongest of the materials, the weaker ones would have been reduced to impalpable fragments, and have been for the most part carried away in the water.

The next operation used to be fermenting. For which purpose the rags were put into a large stone vat and well watered, turning them over from time to time to equalize the moisture. In a few days fermentation began, and was continued till the texture of the rags was so far weakened as to diminish the labour of reducing them to pulp by the subsequent processes. The fermentation from first to last occupied about six weeks, and besides the loss of time, it often happened that the rags being too much heated

acquired a permanent brown colour and were also too much reduced in strength. A well conducted fermentation was considered as contributing greatly to the softness evenness curdled appearance and density of the paper, and probably it possessed advantages that are but ill exchanged for an increased expedition in the manufacture, especially in taking off impressions from copper plates. It is however entirely discontinued in this country, though I believe it still holds its ground in some of the continental paper manufactories.

The next process is that of milling the rags; that is of reducing them by degrees to a fibrous pulp. The mill, omitting all mention of the gearing and wheels and pinions necessary to put the cutters in motion, which could not be understood without figures or models, consists of an oblong trough lined with lead, and divided by a longitudinal partition into two channels, which however communicate freely at their ends, as the length of the partition is not equal to that of the trough. Across the middle of the trough lies an axis carrying a wooden cylinder, the width of which is equal to that of the channel into which it dips. The surface of this cylinder is set with many rows of steel cutters, the points of which come nearly in contact with several rows of similar cutters that are placed upright in a block let into the bottom of the channel. The axis that carries the cutting cylinder may be raised by a screw for the purpose of adjusting the distance between the fixed and moveable cutters.

Water flows into the trough at one end and is discharged at the other end. The cylinder being set at its greatest height above the fixed cutters, the trough is charged with rags, the water is let in and the cylinder is put in motion. The rags as they successively pass between the cylinder and the fixed cutters, are compressed and in a slight degree cut; when the water runs away nearly clear it is a proof that the dirt is now washed out of the rags: the axis of the cylinder is then lowered, the supply of water is diminished, the bleaching powder* is added, and the rags are cut or torn to pieces and bleached at the same time. When this engine called the washer has produced its full effect the rags are reduced to *half stuff*. They are now transferred to another engine similar to the first, but in which the motion of the cutting cylinder is considerably more rapid. Water is supplied as required, but none is allowed to run out of the trough. As the comminution of the half stuff proceeds, smalt is added in order to neutralize the yellow colour even of bleached rags by giving them a bluish tint: the size is also added here if the paper is intended to be printed on, and here likewise are made sundry unauthorized and unacknowledged additions, chiefly gypsum, in order to give a false body and solidity to certain kinds of paper, those especially of which cotton forms the principal ingredient. The

* The more usual modern practice is to bleach the rags in the state of half stuff by exposing them when damp to the action of chlorine gas.

pulp being now finished is run off into a reservoir called the *stuff-chest,* from which it is taken out as wanted for the supply of the vats.

The next process is moulding or forming the paper-stuff into sheets, which is effected in the following manner: The vat is charged with pulp from the stuff-chest, a flue being introduced into the lower part of the vat to keep its contents at the proper temperature. The mould consists of a very shallow rectangular frame, the dimensions of which regulate that of the paper produced by it; the bottom of the frame is made of parallel wires and of others representing the water-mark; or, for the so-called wove paper, wire gauze is employed. On the mould is laid a rectangular frame called the deckle, in order to increase the depth of the mould. The dipper, having previously brought the pulp to a due consistence by diluting it and carefully mixing it with water, lays the deckle on the mould, and taking hold of the mould on each side dips it into the vat in an oblique position, and brings it out again horizontal: a certain degree of vibration is then given to the mould while the water is draining from it, in order to distribute the pulp as evenly as possible. When the water has escaped, the mould is laid on a perforated plank, the deckle is removed, and the dipper proceeds to repeat the same process on a second mould. The first mould passes into the hands of the coucher, who first places it in an inclined position to complete the draining off of the water, here it remains till he has spread smooth a felt of the same size as the mould: he then takes up the mould and applies the face of it

to the felt and then withdraws it, leaving the sheet of paper transferred to the felt. The paper is covered with a second felt on the surface of which a sheet is laid as before, and thus the work proceeds till a pile of alternate sheets and felts has been raised containing 6 quires, or 144 sheets. This pile, called a post, is then placed under a press till the next post is ready. Then it is taken to pieces, throwing aside the felts and placing the sheets accurately one on another. This pile consisting of mere paper is again put into the press, by means of which the greater part of the water is squeezed out and the paper itself becomes more dense even and compact. The sheets are next hung up to dry in parcels of three or four and are then sized, a handful of the thinner sheets, with a sheet of brown paper on the outside to support them, being dipped into the sizing tub at once. The paper is then dried picked and sorted, and lastly smoothed by the action of a very strong press.

A machine for expediting the moulding of paper has been for some years in use, and having received several successive improvements is now (1830) employed by some manufacturers, although I think the general opinion is that *machine paper*, for so it is called, is not so uniform in its composition as that which is moulded by hand. It is impossible by mere words to give more than a very general idea of this machine and its operation. The pulp is duly mixed in the vat, from which it flows through holes fitted with sliders into a trough of the same width as the paper to be made. From the trough it falls in an

equal unbroken sheet or cascade on an endless web of wire-cloth extended horizontally several yards, and kept in a state of constant uniform motion. The pulp is prevented from flowing over the sides of the web by raised borders, between which it moves. By the time that the pulp has been carried on the wire-cloth to the end of its horizontal extent, much of the water will have dripped off through the meshes, and it now comes in contact with an endless band of felt passing over the upper of the two rollers, between which the web is continually going. Here the pulp, being squeezed between the web and the felt, gets rid of the greater part of its water, and, when clear of these rollers, is received on another endless band of felt which carries it between two other rollers, where it is brought to the same state as the paper is after having been couched and pressed in the usual way. At first the paper was found to break very frequently from the difficulty of exactly regulating the speed of the different rollers; but this objection has now been removed by accurate adjustment, so that three or four miles of paper have been of late reeled off without a single fracture.

The complaints of the paper now used in this country, both for printing and writing on, are not merely general but universal; I shall therefore conclude by a few remarks on this subject, not for the purpose of contrasting the produce of rival manufactories, but of pointing out faults that admit of amendment provided the public taste so inclines.

If we take any of the white smooth soft papers,

whether used for writing on, such as the so called Bath post, or for printing on, and burn a slip of it, we shall find that the black coal which it leaves, on being heated just on the outer edge of the flame of a candle, assumes a mealy white appearance, and on being laid on the tongue has exactly the flavour of an earthy alkaline sulphuret. It is therefore highly probable that such papers contain gypsum or sulphate of barytes, added both for the purpose of increasing their weight and their compactness. The consequence of this adulteration is great brittleness of the paper and a peculiar creaking noise in writing on it, arising from the friction of the earthy particles, which soon wear out the point of the pen.

Our harder more rattling papers, such as common foolscap and post, are distinguished from those already mentioned not only by their greater hardness and firmness but also by their blue tint. They appear to contain little if any cotton or gypsum, but, in order to neutralize the pale yellowish brown colour which the rags naturally have or acquire from the action of the bleaching powder, the manufacturer adds smalt or powder blue. If a paper of this description is viewed by a magnifier it will be found to be full of minute particles of a blue colour, which are the smalt: but smalt is only a glass deeply coloured by cobalt and ground to powder, all such papers therefore may be considered as a finer kind of sand or glass paper, and therefore the great rapidity with which the pen wears out when employed in writing on them, is not to be wondered at, though very annoying to those

who have to write much. Chambers, the editor of the first Cyclopedia, is recorded to have written a couplet celebrating the single pen with which he completed the whole of that work, a feat which certainly no modern writer could accomplish. The rapid destruction of pens in modern times has by many been laid to the fault of the geese, as if, corrupted by luxury and high feeding, they had become effeminate and incapable of producing good quills. It is much more probable however that this defect is to be charged to the account of the papermakers than of the geese, and the causes that I have assigned are I think quite sufficient.

Among all the specimens of paper a century old, both foreign and English, that I have examined, I have not been able to detect any smalt either by the magnifier or by a blue given to their ashes when strongly heated, whereas the ashes of common post paper after exposure to the blowpipe become of a very deep blue, showing the large quantity of smalt that they contain.

Another defect of paper is its tenderness and liability to become yellow-brown and rotten after a few years. This is owing to over bleaching by the use of oxymuriate of lime or of chlorine in substance, instead of the old method by exposure to the sun. It is true the present practice is by far more expeditious, and therefore answers admirably well the object of the manufacturer, who, provided the article that he produces does not deteriorate faster than the same

from his neighbour's or rival's manufactory, is well content. Another defect is the tenderness sponginess and want of durability in paper. This mainly arises from the intermixture of cotton with the linen, often in a very large proportion. The historical fact that linen paper soon drove out of the market the cotton paper that had preceded it, is such a proof of the great inferiority of the latter as a material for paper as requires no more to be said. But the remedy for this evil is not so obvious. The immense and continually increasing demand for paper, and the diminishing consumption of linen and hempen cloth in comparison with cotton in every part of Europe, must necessarily afford an increasing quantity of cotton rags and a diminishing one of linen rags. I see therefore no chance, under such circumstances, of avoiding the defects in paper that arise from this cause, except by the discovery of some raw material as good as flax or hemp, and which can be brought into the market at the same price as rags. Innumerable experiments have been made with this view, and innumerable substitutes have been proposed; many decidedly inferior even to cotton, many much better but probably not to be obtained at all in quantity, or at least at a price sufficiently low to induce the paper maker to adopt them. Dr. Schaeffer several years ago published two volumes of specimens of paper made of a mixture of common paper-stuff with the proposed substitutes. All the specimens of his that I have seen are bad, both as regards their

colour and tenacity, and the only European substances which, in my opinion, can reasonably be looked to with any hope, are the tough barks of some trees and shrubs, chiefly aquatic: of these the most promising seem to be certain species of Salix, Cornus, Daphne and Viburnum.

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THE END.

London: Printed by Samuel Bentley, Bangor House, Shoe Lane.